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JOURNAL

OF THE

Elisha Mitchell Scientific Society

(Official Publication of the N. C. Academy of Science)

ISSUED QUARTERLY

CHAPEL HILL, N. C., U. S. A.

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EDITORS OF THE JOURNAL.

W. C. COKER.

J. B. LATTA, ARCHIBALD HENDERSON.

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JOURNAL

OF THE

ELISHA MITCHELL SCIENTIFIC SOCIETY

(Organ of the North Carolina Academy of Science)

VOL. XX. NOV. 1904

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY.

OCTOBER 13, 1903.

Professor *Collier Cobb*, President, in the chair.

The following papers were presented:

The Use of the Vector Diagram in Electrical Engineering. *J. E. Latta.*

Tanning. *Charles Baskerville.*

A New Indicator. *E. V. Howell* and *A. S. Wheeler.*

The Influence of the Spermatozoon on the Larval Development of the Sea Urchin. *H. V. Wilson.*

CHARLES BASKERVILLE,
Recording Secretary.

BUSINESS MEETING, OCTOBER 13, 1903.

The following were elected as members: From Chapel Hill—Wm. McK. Marriott, L. B. Lockhart, W. H. Oldham, W. A. Whitaker, George MacNider, W. W. Eagles, Greene Berkeley, F. H. Gregory; from Raleigh—Joseph Graham, M. D.

The following arrangement with the North Carolina Academy of Science was approved: The Elisha Mitchell Journal assumes the publication of the proceedings of the Academy in its initial number; the Journal is to be enlarged to 200 pages and to be issued quarterly; the Academy is to

[Issued 20th November.]

pay annually the sum of one hundred dollars towards the support of the Journal; the editing and issuing of the Journal is to remain in the hands of the Elisha Mitchell Society; the Journal is to retain its name, but upon the title cover will appear in small letters, "Official Publication of the North Carolina Academy of Science;" each member of the Academy is to receive gratis one copy of the Journal; associate members are to receive only the first number of the volume following the meeting at which the subscriber was an associate.

An invitation was extended to the North Carolina Academy of Science to hold its next annual meeting at the University November 12th and 13th. Professors Gore, Coker and Wheeler were appointed a committee of arrangements.

The following officers were elected for the ensuing year:

President, *Charles Baskerville.*

Vice-President, *J. E. Latta.*

Recording Secretary, *A. S. Wheeler.*

CHARLES BASKERVILLE,
Recording Secretary.

JANUARY 12, 1904.

Mr. *J. E. Latta*, Vice-President, in the chair.

The following paper was presented:

Elements, Verified and Unverified. *Charles Baskerville.*

A. S. WHEELER,
Recording Secretary.

FEBRUARY 9, 1904.

Professor *Charles Baskerville*, President, in the chair.

The following papers were presented:

Mendel's Law of Heredity. *W. C. Coker.*

Incomplete Division in Vertebrate Animals. *H. V. Wilson.*

Composition of Coastal Plain Sands in Relation to Distance from Existing Shore Lines. *Collier Cobb.*

A. S. WHEELER,
Recording Secretary.

MARCH 8, 1904.

Professor *Charles Baskerville*, President, in the chair.

The following papers were presented:

Mercerisation. *A. S. Wheeler.*

The Work of the Digestive Glands. *I. H. Manning.*

Kunzite, the New Gem; Its Unique Properties (with demonstrations). *Charles Baskerville.*

A. S. WHEELER,
Recording Secretary.

APRIL 12, 1904.

Professor *Charles Baskerville*, President, in the chair.

The following papers were presented:

The World's Production and Consumption of Coal. *C. L. Raper.*

Grafting in Vertebrate Embryos. *H. V. Wilson.*

Protozoa in Smallpox. *R. H. Whitehead.*

A. S. WHEELER,
Recording Secretary.

BUSINESS MEETING, SEPTEMBER 12, 1904.

Professor *F. P. Venable*, Corresponding Secretary, in the chair.

The following officers were elected for the ensuing year:

President, *Wm. Cain.*

Vice-President, *J. E. Mills.*

Corresponding Secretary, *F. P. Venable.*

Recording Secretary, *A. S. Wheeler.*

Editorial Committee on the Journal, *W. C. Coker, J. E. Latta, Archibald Henderson.*

A. S. WHEELER,
Recording Secretary.

SCIENCE AND THE PEOPLE.*

CHAS. BASKERVILLE.

Opportunities beget responsibilities. On such an occasion as this, he who has been honored with the opportunity is tempted to address you upon a specialized subject to which he has given years of thought and interest, but the opportunity carries with it corresponding responsibilities beyond the narrow bounds of one's limited investigations. The audience is composed in part of the general public, which is more or less informed, or misinformed through no self-fault, as to the general trend of scientific thought and movement; in part of students, some enwrapt with the beauty and majesty of ancient art and philosophy, others versed in the history of science and conversant with its latest conceptions; in part, my hearers are specialists in the varied branches of science, so I feel much like Moleschott in his address at the reopening of the University of Rome, when he found himself "in the face of an audience whom he had nothing to teach, but from whom he had much to learn."

The groundwork of science may be thrown into three divisions: (1) laborers who work; (2) tools they must employ; and (3) that which constitutes the fields of their labors.

In the world we know there is such a thing as progress; that civilization is dependent upon something capable of increase, evidently knowledge. Although, as Schiller has said, "Knowledge is to one a goddess, to another an excellent cow." yet the momentum of progress is largely, if not altogether, given by science.

Variation in social conditions have caused variations in

*Retiring address of the president of the North Carolina Academy of Science. Wake Forest College, May 13, 1904. Science, *20*; 266–273. 1904.

human standards of morality, but through all the ages morality has actually been a stationary thing. Different ages have known mighty things in literature and art, but each was the individual outcome of the pen or the brush of the genius, who bequeathed a heritage of his own labors as a stimulus to others; but the mastership passed with him. Not so with science; for, as Whewell has said, "It is not a collection of miscellaneous, uncorrected, unarranged knowledge that can be considered as constituting science."

Different ages have known mighty things in science, sometimes as the outcome of a genius, but equally as often the consequence of talent building upon that which was learned before. So, never was one more mistaken than President Woodrow Wilson when he stated that science breaks with the past.

In order to appreciate the spirit of modern science, we must take a hurried glance at the motives prompting the older workers and consider their environment. We are aware, in the historical development of things, that all present knowledge arose from a chaotic state enveloping itself in mystery. This was due to the empirical means of observation, superstition attending any inquiry into the why of things, hampering circumscriptions of religions, primitive and more recent, and lack of means of communication. The wise man, exercising a little common sense, wrought cures wonderful in those dark times, many simple for the youngest practitioner of today. While, doubtless, some were prompted by an earnest desire to do good, many were actuated by greed of power and gain, even as today. Fearful of their loss once secured, they often sought to hide their own shortcomings and take advantage of the universal ignorance by their mysticism. These were not the sole motives of all workers, however. The spirit of inquiry has ever been present with mankind. For

> "Ignorance is the curse of God,
> Knowledge the wings wherewith we fly to heaven."

Although, three hundred years before Christ, the living

and dead were dissected at the Alexandrian school, it was not until the fifteenth century that the popes overcame popular prejudice about the sancity of the dead body and issued edicts permitting dissection. The following century, Vesalius arose, and then Harvey discovered the circulation of the blood. Greek philosophers first endeavored to place science upon a purely rational basis and they were accused of impiety. To be sure, it may be said that such impeachments have not ceased to sound for over two thousand years and cost the lives of many good and noble men. The church considered Galileo and similar workers as rank heretics. Certain scientific endeavors were tolerated, and the knowledge gained confined within monastic walls. In the hearts of some was that yearning to make known the truths they had dreamed; and monks like Roger Bacon, Basil Valentine and Berthold Schwartz put forth writings so mysterious as to be incomprehensible to many, but having hidden realities not previously made known.

Science was centuries acquiring its natural voice. In the dark ages only a small band of learned folk made itself known, yet the voice of Kepler, saying "The scientist's highest privilege is to know the mind and think the thougts of God," sounded three centuries ago, has echoed with increasing reverberations to our own time. Science, harassed by ding-dong, useless and unnecessary authority, was driven into rigid pious paths. As the very spirit of science is inquiry, it lives upon liberty and would not be bound by authoritative misconceptions. It is not strange, then, that in a democracy of thought permitting the widest range of opinions men should have been borne away to the other extreme, and such catching expression as "every one for himself and no god for any one," became prevalent. "Scientific arrogance" was a pet expression of theologians who trespassed none the less than had the scientists. "The abuse heaped upon Newton for substituting blind gravitation for an intelligible Deity" that John Fiske tells about, was nothing in comparison with the subsequent treatment of geologists by theologians for disturbing the

Bibical chronology. The highest teaching of scientific verities is the absolute necessity for the existence of God. In fact, one need not go far for a chemical confirmation of the resurrection, as death is but a phase of our continual internal change; "so when this corruptible shall have put on incorruption and this mortal shall have put on immortality," our natural body sown in dishonor and weakness, shall be raised a spiritual body, clothed in glory and power; "and as we have borne the image of the earthly, we shall also bear the image of the heavenly." It is only in the most modern times that the scientific spirit, which looks to the relative and temporarily excludes the absolute, has begun to be fully applied and extended to ideas of every order.

I am by no means unmindful of the dogmatism of science at times, for it may be recalled that Daguerre was actually temporarily incarcerated in an asylum because he maintained he could transfer his likeness to a tin plate; Franklin's paper on lightning conductors was laughed at and not published by the Royal Society; and Galvani was attacked by his colleagues, designated a know-nothing, and called "the frog's dancing master." The Count de Gasparin even wrote in the *Journal des Debats*, "Take care; the representation of the exact sciences are on their way to become the inquisitors of our days."

Science does not pretend to say the last word in regard to the universe, but it builds hypotheses upon observed and unobserved facts which are altered or cast aside in the light of all new correctly obtained facts. It is ever ready to declare the increasing uncertainty of many delightful and ideal conceits, which is not to be taken as vacillation, but as evolution, growth. The late distinguished Lord Playfair at the Aberdeen meeting of the British Association said: "The changing theories which the world despises are the leaves of the tree of science drawing nutriment to the parent stems, and enabling it to put forth new branches and to produce fruit; and though the leaves fall and decay, the very products of decay

nourish the root of the tree and reappear in the new leaves or theories which succeed." With this spirit, it will not hesitate to attack any of our pet scientific, sociological or theological dogmas, which are frail as all human system must be. These attacks are without venom, however, for "Science * * * requires for its satisfactory prosecution the employment of our very noblest powers, and it is by them alone that we can hope to attain a knowledge of the most supreme and ultimate truths which our intellectual faculties have the power to apprehend."—(Mivart.)

Although Gough remarked to Dalton, "The human mind is naturally partial to its own conceptions and frequently condescends to practise a little self-delusion when obliged by the force of facts and argument to abandon a favorite notion," the supreme lesson in the history of science, most marked in our own time, is the pursuit of truth. Much time has been spent in defining *art* and casting that which did not fit a pet definition into a rubbish box called *science*, or "natural knowledge" as a member of the Royal Society was pleased to term it. Many of those insisting upon such a classification are not without reason, for have not certain phylogenetics promulgated on the flimsiest excuse some *pan mixia*, as Weisman's germ-plasm theory and then easily remembering the conclusions, but forgetful of the evidence, maintained that it was a law? Or has not a Tesla over magnanimously taken the public into his confidential conversations with the inhabitants of Mars?

It has been fashionable in years gone by to say that poetry and truth were antagonistic. Coleridge and Poe, I think, insisted that science and poetry were irreconcilable. Incongruous statements, as when Shakespeare speaks of toothache "as humor or a worm", doubtless gave rise to such thoughts. The Avon poet put it according to the scientific teachings of his time. Civilization and methods of interpreting the truth change and progress, but truth itself is eternal. Science will

no more replace literature than can a geometric diagram be substituted for a landscape painting.

Science, to be sure, is destructive of conventions. Freedom is the breath of science, and the unshackled movement of boundless human curiosity must effect literature. Men of science look not pleasantly upon their scavenging camp followers, who, riotous in thought, indulge in a license of speech which provokes quite justly those who conscientiously differ from them, and unfortunately inculcates ideas in those unable to winnow the chaff from the grain.

Thus it may be seen that modern science makes for purity and genuineness. There is nothing more abhorrent to a man of science than the pretenses of a scientific mountebank. This elevation is dual in its effect, general and local. As an evidence of the former there have resulted ameliorated conditions of society by protecting food from harmful adulterations, improved sanitation, better and more reasonable treatment for diseases, general distribution of the products of wealth among all civilized peoples, and in many other ways too numerous to mention. A reader after Count Tolstoy and his "recognition of the bankruptcy of experimental science," can not but be impressed with his earnestness, and yet feel that he looks only very close at home when he writes: "The men of science of our time think and speak and the crowds follow them, while at the same time there was never a period or a people among whom science in its complete significance stood on so low a level as our science to-day. One part of it, that which should study what makes life of man good and happy, is occupied in justifying the existing evil conditions, while another part spends its time solving questions of idle curiosity." He does not apparently realize that science promotes a certain continuity of ideas, as well as the intellectual and moral education of the nations.

"There exist, indeed and always will exist, many deplorable things, much suffering, and much wickedness in the world; but it is to the credit of science that, instead of lulling

mortals with the feeling of their powerlessness into passivity of resignation, it has urged them to react against destiny, and has taught them the sure way by which they can diminish the sum of woe and injustice, and increase their happiness and that of their fellows. It has not accomplished this by means of verbal exhortation or *a priori* reasoning, but by virtue of processes and words really efficacious, because they are acquired from the study of conditions of existence and the causes of evil."

Further, as the editor of *The Popular Science Monthly* has said:

"The advance of science is evidenced in numberless ways, but our weightiest proof of it is found in the gradual acceptance of enlarged in place of narrower views of the subject. New discoveries are important; the widening of the ranges of research is important; the extension of generalization and better organization of positive knowledge are important; but more inportant still is the growing general recognition that science is the grand agency in modern times for reshaping the common opinions of the community."

The local elevating effect of work in pure science is the taking a man away from the sordid things of the world, and

"No life can be pure in its purpose, and strong in its strife,
And all life not be purer and stronger thereby."

By this I would not be understood as placing him who works only in pure science on a pedestal, or intimate that he is superior to the other who makes a practical outcome of his scientific work the main object. I am well aware of the eloquent statements about this being an industrial age and the duty of young men te seek a technological education. Far be it from my purpose to exhibit the least antagonism to the generalspirit of such appeals, for I endeavor to teach much of the same thing, but in it all and with it all, I would urge that the pure science be either kept ahead or abreast of commercial progress. Neither the pure nor the practical deserves to be developed alone. They are inter-dependent and have

always grown together. The pure research has been utilized later in practise. Industrial demands have stimulated investigation. Illustrations abound. The destiny of nations has been changed by scientific investigations prompted either by search for research sake or by a commercial call. The history of indigo reads like a novel, for chemists have accomplished the task, not of producing artificial indigo, but the genuine indigo by artificial means. The modern spirit of pure science thus elevates man's ideals and that of the applied adds to his comfort, pleasure and happiness.

In advocating Du Bois Reymond's "Hellenism" or the love of humanistic and scientific culture for its own sake, apart from all considerations of profit and advantage, I would not be understood as

> "Nourishing a youth sublime
> With the fairy tales of science."

While I maintain that the dollar should not be the guiding star, there is no objection to dwelling upon the practical value of science; for, as Huxley has said: "it has become obvious that the interests of science and industry are identical; that science can not make a step forward without, sooner or later, opening up new channels for industry; and, on the other hand, that every advance of industry facilitates those experimental investigations upon which growth of science depends."

It is well understood by those who have knowledge of the problem that the first line of defense in industrial warfare is the educational centers. We are a great industrious and prosperous nation. Prosperity is the possession "of enlarging opportunities to secure the gratification of our material, intellectual, social and spiritual wants."

In the foregoing I have endeavored to show that science is an evolution. In the past, to be sure, at times it has marched with crippled steps, at present it is gripped into the vitals of nations. The modern spirit of science towards religion is sane and healthy; towards literature it leans in offering themes alive and seeking graceful modes for its

expression; it fosters and grows with industry, so "to choke the fountains of science is to dry the source of our prosperity."

The progress of science among us very largely depends, as Draper has said, on two elements; first, our educational establishments: and second, our scientific societies.

School men within the past decade have learned that it is proper to send the whole boy to school and little by little science has come into the curriculum. There is room for much more sane science and its more widespread teaching, and it should be better taught. Let us teachers then have more to do with pushing the proper recognition of science before the attention of school boards, insisting upon adequate compensation, and let us have men and women ready-equipped for the work. Pardon a personal illustration. I use it solely because I know whereof I speak. Every year there go out from our laboratory at the university a dozen or more graduates who, with rare exceptions, and they are mainly my own assistants, are offered position in other states. We can change this, and I take it as one of the things this academy may hold out for its accomplishments. How?

We teachers can and must get out and see the schools, confer with the boards, speak to the people, in short, see that wholesome works in science are placed in the libraries, tell of common sense science, hygiene, assist the great work and create like things to the farmers' institutes, popularize science. There is "no discredit in popularizing science," as Mendenhall said, "that popularizing what is not science is the thing that is to be shunned and avoided."

This brings to our immediate attention the instructors in the various institutions that are making the teachers, making the preachers, the lawyers, the doctors, business men and the citizens. Boards of trustees must be made to clearly understand that time and equipment for these things must be had; boards of trustees must be made to understand that the best teachers are those who contribute something to that sub-

ject they would have better known and appreciated; boards of trustees must be impressed with the fact that with our present arrangements, most researchers must steal the time necessary from rest, sleep, social concernments and family pleasures and that is not right, it is not just to make them mere teaching machines.

There is no question whatever but that many of the teachers in our institutions do the treadmill. All of this can not with justice be laid at the doors of our honorable governing bodies, however, for teachers are vain as other mortals. Some insert in catalogues a vast array of special courses, which either are solely for show, or, if they be given of necessity, can not be with that fresh vigor which should characterise instruction. The man who does that voluntarily loves not really his science. It is far wiser to offer a few courses, give them well and contribute a bit, even a mite, to the sum of knowledge. I do not know but that the late Professor Rowland was a bit severe, yet I wish to quote from an address of his on a "Plea for Pure Science". Some children may be coaxed, others require whipping.

"It is useless to attempt to advance science until one has mastered the science; he must step to the front before his blows can tell in the strife. Furthermore, I do not believe anybody can be thorough in any department of science, without wishing to advance it. In the study of what is known, in the reading of the scientific journals, and the discussion therein contained of the current scientific questions, one would obtain an impulse to work, even though it did not before exist. And the same spirit which prompted him to seek what was already known, would make him wish to known the unknown. And I may say that I never met a case of thorough knowledge in my own science, except in the case of well-known investigators. I have met men who talked well, and I have sometimes asked myself why they did not do something; but further knowledge of their character has shown me the superficiality of their knowledge. I am no longer a believer in men who could do something if they would, or would do something if they had a chance. They are imposters. If

the spirit is there, it will show itself in spite of circumstances."

Your speaker wishes to plead with his southern colleagues for greater activity in research. Many have told me they had no appliances. Liebig had none at first and later bought most or that which he had from his slender stipend; Priestley utilized a lens and sun's heat and discovered oxygen, Wöhler distilled potassium, using a bent gun barrel as a condenser in in Berzelius's laboratory. Where there's a will, there's a way. There is much unknown, so much to learn, and, as Victor Meyer has said, there is "the gaining of gold from rubbish."

Yes, our equipment is meager; poorer than it ought to be for states now far richer than ever in their history; grown rich, too, as a result of the progress of industries. Science sowed the seed of the present prosperity and it is worthy of remembrance, thanks, reward. And these will come. In a measure, they have come. Every scientific man in the state takes pride in the growth of the new biological building at this institution, beneficent generosity of a prominent trustee at Trinity college equipping the physics department, the conduct of the soil survey under the direction of the Department of Agriculture, the Beaufort laboratory, etc.

The importance of promoting science as the duty of the states was well known to the ancients, especially the Greeks and Arabs. The Prince Consort, in an address before the British Association in 1859, made the following statement:

"We may be justified in hoping * * * that the legislature and the state will more and more recognise the claims of science to their attention; so that it may no longer require the begging-box, but speak to the state like a favored child to its parents; sure of his parental solicitude for its welfare; that the state will recognize in science one of its elements of strength and prosperity; to foster which the clearest dictates of self-interest demand."

The endowment of any laboratory in any institution of the state but helps the others. There is no such thing as com-

petition in doing good. The blanket of ignorance may be lifted a bit higher here than there, but each lifts and gives the fresh air of knowledge to those smothering beneath.

So, my friends, in fulfilling the responsibilities begotten of the honor, allow me in closing to give my conception of the destiny of this academy.

Man depends much for his happiness upon the sympathy of those around him; "it is rare to one with courage to pursue his own ideals in spite of his surroundings." So science thrives best where societies exist for its advancement. Science speaks a universal language and knows no geographical, political or social boundaries, otherwise Humphrey Davy would never have been so cordially entertained by his French colleagues when the shores of England and France bristled with bayonets in bloody antagonism. Then let us thank God for the brotherhood of science, for the science, the spirit of modern science, is at war with war. The right spirit of science is that of patient inquiry; of longing for the truth, cost what it may in brain power, energy, money or self denial; it is the spirit of cooperation as wide as the needs of man; of constructive effort through slow accretion by many years. "The touch of science makes the whole world kin."

MOLECULAR ATTRACTION.*

(SECOND PAPER.)

BY J. E. MILLS.

REVIEW OF THE THEORY.

This paper presents additional evidence tending to show that the attraction between molecules varies inversely as the square of their distance apart and does not vary with the temperature. Considering the attraction as a property belonging to each molecule, or to be more exact, a mutual property of each pair of molecules, it must vary as the mass, large numbers of similar molecules being here considered. Briefly therefore this paper is an attempt to show that the *law of gravitation* holds, not only between masses, but between the molecules of a substance, and that this law is alone sufficient to account for the phenomena of the internal latent heat of vaporization.

The assumptions upon which the present work is based are stated in the original paper,[1] and it would not be necessary here specifically to call attention to them were it not for the fact that certain reviews have overlooked the significance of the preliminary statements to that paper. We may say that the steps leading up to the present work are briefly:—

1. The kinetic theory of gases and van 't Hoff's application of the gas law $PV = RT$ to solutions.

2. The conclusion from the above theories and related work that the average translational energy of gaseous and liquid molecules must at the same temperature be equal.

*Reprinted from the Journal of Physical Chemistry, Vol. 8, No. 6, June, pp. 383–415 (1904).

[1] Jour. Phys. Chem. 6, 209 (1902).

2. The belief based on the study of the specific heat of gases, that the *total* energy of a gaseous molecule, exclusive of the energy which holds the molecule together and of extraneous forces, is proportional to the translational energy.

4. The inference, for it is somewhat more than a mere assumption, the causes for 3 being considered, that the *total* energy of a molecule of a liquid would similarly be found to be proportional to its translational energy.

These four preliminary steps may be summed up by the statement that the total energy *per se* of a molecule must be the same in the liquid as in the gaseous state, the temperature being the same. If at a given temperature a given weight of gas represents more energy than the same weight of the substance as a liquid, the extra energy of the gas must be energy of position only (assuming no intramolecular change).

We made no attempt in the former paper, and we make none in this, to prove the last statement above, or to give the evidence for it. To do so even cursorily would require a discussion of the kinetic theory of gases, their specific heats more particularly, and the modern theories of solution. The statement is here made only as the belief of the author upon which the present work is based. Many citations of closely related belief might be given. Oswald[1] gives a clear and succinct statement of 1 and 2. O. E. Meyer[2] shows the grounds for 3. The author has published[3] the study which led him to conclude that 4 was a reasonable supposition. So long ago as 1885, Ramsay and Young made practically the same statement.[4]

[1] Solutions pp. 147, 148.

[2] Kinetic Theory of Gases, p. 117.

[3] Journal of the Elisha Mitchell Scientific Society, Vol. 18 (1902).

[4] Phil. Trans. **1886A**, Evaporation and Dissociation, p. 72, Section 4; *c* and *d* of that section not being necessary under the limitation imposed above that there should be no intramolecular change, and *e* and the footnote being unnecessary in the light of the later work of van 't Hoff.

Expressing the above belief in a different form, we may say that the energy necessary to change a liquid into a gas must then be spent solely in overcoming the external pressure and in altering the distance apart of the molecules. (Unless the molecule breaks apart also or nears the point of disruption.)

Denoting the energy spent in overcoming the external pressure by E_1, this energy can be calculated from the equation,

[1] $$E_1 = 0.0_4 31833\ P(V - v)\ \text{cals.},$$

where the unit calorie is from 15° to 16° C, P is the pressure in millimeters of mercury, V and v are the volumes before and after expansion. To obtain the constant, $0.0_4 31833$, we used the values: density of mercury, 13.5956; Rowland's value of the therm, corrected by Day, at 15° to 16° C, 41880000 ergs, as unit; and gravity taken as 980.5966.

Denoting the total latent heat by L, we have $L - E_1$ as the energy spent in overcoming the molecular attraction at any particular temperature.

On the further assumption:

5. That the molecular attraction varies inversely as the square of the distance apart of the molecules, the equation 7 (p. 212) of the original paper was derived, which equation readily takes the more convenient form,

[2] $$\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant},$$

for any particular substance, where $L - E_1$ is the internal latent heat of vaporization, and d and D are the densities of liquid and vapor at any particular temperature.

With regard to this equation, we will here say that it was designed to test the assumption advanced in 5. Had it failed to produce a constant or some function of the temperature, the author hoped to substitute 5 by some other distance function of the attraction, obtain the formula similarly, and thus repeat until the correct assumption was made.

As to the mathematics by which it was derived, the

vagaries of a particular molecule cannot of course be followed. But in considering energy relations we commit no error by considering the average molecule as was done. The formula should therefore hold strictly true provided:—

(*a*) The molecules are evenly distributed.

(*b*) The number of molecules does not change.

(*c*) No energy is spent in intramolecular work.

(*d*) The attraction does not vary with the temperature.

Or, we might sum up *a*, *b*, *c*, and *d*, by saying that formula 2 should hold, provided we are dealing with a stable chemical compound whose molecules are not associated.

The first paper tested the formula so far as the direct measurements of latent heat and the related data permitted. The agreement appeared to be much too close to be the result of accident, but where variations in the data as given by different observers amounted often to five and ten per cent., any close agreement was impossible. It being impracticable to make direct measurements of the latent heat at widely different temperatures, attention was called to the measurements of Ramsay and Young and of Dr. Young. These measurements give the vapor pressure and density of liquid and vapor, at corresponding temperatures over a wide range of temperature for thirty-one substances. The present paper deals with twenty-one of these substances, the calculations for the ten esters being not yet completed.

THE MEASUREMENTS.

The complete measurements used are given in the appended tables.

The few exceptions to the following general statements are noted below.

(*a*) The vapor pressure, density of the liquid, and density of the vapor, are from the measurements, references given below, by Professors Ramsay and Young, or Young.

(*b*) The vapor pressures from Biot's formula were used in preference to the observed values.

(*c*) Where calculated the density of the vapor was obtained from the formula,

$$[3] \qquad D = 0.0_4 16016 \frac{P\,m}{T},$$

where P is the pressure in millimeters of mercury, m is the molecular weight, oxygen equal to 16 as the standard, and T is the absolute temperature. The constant $0.0_4 16016$ was obtained by the use of the values $0.0_4 89873$ for the density of hydrogen at 0° C, 760 mm. pressure, latitude 45° and sea level, and 0° C = 273° absolute.

(*d*) The densities of the vapor given are often carried one place further than the accuracy of the measurements would warrant. This was because the density of the vapor was not always given directly in the original paper, and in the necessary transposition the additional figure of the calculation was retained.

(*e*) Making use of the well-known thermodynamic equation,

$$[4] \qquad L = \frac{\delta P}{\delta T} \frac{T}{J} (V - v),$$

the latent heat of vaporization for methyl, ethyl and propyl alcohols, acetic acid, and ether, were calculated and given in the original papers, where the method in detail may be obtained. The latent heat for water, 0° to 230° C, is from Regnault. The latent heat for benzene, 0° to 270° C, is from Tsuruta,[1] using measurements of Young.

(*f*) In all other cases the latent heats were calculated by the author, the following method being used. Biot's general formula for the vapor pressure,

$$[5] \qquad \log P = a + b\alpha^t + c\beta^t,$$

has been found with properly chosen constants accurately to represent the vapor pressure, Differentiating and changing base of the logarithms from natural to Naperian we get:

$$[6] \qquad \frac{\delta P}{\delta t} = \frac{P}{m^2} (b \log \alpha\alpha^t + c \log \beta\beta^t)$$

[1] Phys. Rev. 10, 2 (1900).

where $m = 0.434294$. Substituting this value of $\frac{\delta P}{\delta T}$ in equation 4, we get:

$$[7] \qquad L = 5.3019 \frac{P(V-v)T}{J}(b \log \alpha\alpha^t + c \log \beta\beta^t);$$

and using values for P and J already adopted (p. 82), we have finally:

$$[8] \quad L = 0.0_3168775\ P.\Delta v.T\ (b \log \alpha\alpha^t + c \log \beta\beta^t), \text{ cals.; or}$$

$$[9] \qquad L = \frac{P.\Delta v.T}{10^6} A \text{ cals., if,}$$

$$[10] \qquad A = 168.775\ (b \log \alpha\alpha^t + c \log \beta\beta^t).$$

In this form the calculation of the latent heat is not only theoretically correct, but is much shortened in comparison with the usually adopted methods. The values for A were obtained from the constants for Biot's formula given in the original papers, and the equations thus derived for each substance are given below under that substance.

(*g*) All calculations in this paper were checked and every effort was made to make the calculations as accurate as the data from which they were derived.

Ether. See Table 2. Data from Phil. Trans. 1887A, p. 57; except density of liquid at 10°, 20° and 30° C, where the values are from Oudemans. Molecular weight used 74.08.

Di-isopropyl. See Table 3. Data from Jour. Chem. Soc. 1900, p. 1126, except vapor pressure at 216° and 225° C (calculated from Biot's formula); and vapor density at 0° C which is theoretical. Molecular weight used, 86.112. For calculation of the latent heat,

$$A = \text{antilog } (\bar{1}.572552 - 0.00020800t) + \text{antilog } (0.1268648 - 0.00466932t),$$

where $t = t°\ C + 10$.

Di-isobutyl. See Table 4. Data from Jour. Chem. Soc.

1900, p. 1126, except vapor pressure at 274° C (calculated from Biot's formula); and vapor density at 0° C which is theoretical. Molecular weight used, 114.144. For calculation of the latent heat,

$$A = \text{antilog } (\bar{1}.1739925 + 0.00104426t) + \text{antilog } (0.2271234 - 0.00380225t),$$

where $t = t°\ C - 10$.

Isopentane. See Table 5. Data from Proc. Phys. Soc. 1895, p. 602; except vapor density at 0° C which is theoretical. Molecular weight used, 72.10. For calculation of the latent heat we have,

$$A = \text{antilog } (\bar{1}.6310169 - 0.00031549t) + \text{antilog } (0.1373762 - 0.00515903t),$$

where $t = t°\ C + 30$.

Normal Pentane. See Table 6. Data from Jour. Chem. Soc. 21, 1897, p. 446; except vapor density at 0° C which is theoretical. Molecular weight used is 72.10. For calculation of the latent heat, we have,

$$A = \text{antilog } (\bar{1}.7496468 - 0.00073363t) + \text{antilog } (0.0668185 - 0.00551392t),$$

where $t = t°\ C + 20$.

Normal Hexane. See Table 7. Data from Jour. Chem. Soc. 1895, p. 1071; except vapor density at 0° C which is theoretical. Molecular weight used is 86.11. For calculating the latent heat, we have,

$$A = \text{antilog } (\bar{1}.3604438 + 0.00042355t) + \text{antilog } (0.2029359 - 0.00411255t),$$

where $t = t°\ C + 10$.

Normal Heptane. See Table 8. Data from Jour. Chem. Soc. 74, 1898; except vapor density at 0° C which is theoretical, and vapor pressure at 266° and 266.5° C which is calcu-

lated from Biot's formula. The molecular weight used is 100.13. For calculation of the latent heat, we have.

$$A = \text{antilog } (\bar{1}.3407071 + 0.00053408t) + \text{antilog } (0.2342860 - 0.00403623t),$$

where $t = t°$ C.

Normal Octane. See Table 9. Data from Jour. Chem. Soc. 1900, p. 1145; except vapor density at 0° C which is theoretical. The molecular weight used is 114.144. For calculation of the latent heat, we have,

$$A = \text{antilog } (\bar{1}.3927781 + 0.000342913t) + \text{antilog } (0.2497609 - 0.004006534t),$$

where $t = t°$ C $- 10$.

Benzene. See Table 10. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except density of vapor at 0° C which is theoretical. Molecular weight used is 78.05. Latent heats were calculated by Tsuruta (Phys. Rev., 1900, p. 116), except at 0° C, where the value found by Griffiths and Marshall is used, and at 280° C where the calculation was made by the author.

Hexamethylene. See Table 11. Data from Jour. Chem. Soc. 1899, p. 873; except vapor density at 0° C which is theoretical. Molecular weight used is 84.096. For calculation of the latent heat, we have,

$$A = \text{antilog } (\bar{1}.2956115 + 0.00049715t) + \text{antilog } (0.1878242 - 0.00391252t),$$

where $t = t°$ C.

Fluo-benzene. See Table 12. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except the vapor density at 0° C which was calculated. Molecular weight used is 96.09. For calculation of the latent heat, we have,

$$A = \text{antilog } (\bar{1}.13157974 + 0.000942654t) + \text{antilog } (0.2224140 - 0.00363024t),$$

where $t = t°$ C.

Chlor-benzene. See Table 13. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except vapor density at 0° C which is theoretical. The molecular weight used is 112.5. For calculating the latent heat, we have,

$$A = \text{antilog } (\bar{1}.2268791 + 0.00075845t) + \text{antilog } (0.1846519 - 0.00359227t),$$

where $t = t°\ C - 30$.

Iodo-benzene. See Table 14. Data from Jour. Chem. Soc. 1889, p. 486, and 1891 p. 125; except vapor density at 30° and 100° C which is theoretical. Molecular weight used was 203.9. For calculating the latent heat, we have,

$$A = 0.09891873 \{ \text{antilog } 0.0014219821t + \text{antilog } (1.28759778 - 0.00324574t) \},$$

where $t = t°\ C - 30$, a form of the equation less convenient for calculation than the one usually adopted.

Brom-benzene. See Table 15. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except vapor density at 30° and 100° C which is theoretical. Molecular weight used was 157.0. For calculation of the latent heat, we have,

$$A = \text{antilog } (\bar{1}.8373717 - 0.00095092t) + \text{antilog } 0.0763464 - 0.00489465t),$$

where $t = t°\ C - 30$.

Carbon Tetrachloride. See Table 16. Data from Jour. Chem. Soc. 1891, p. 911; except vapor density at 0° C which is theoretical. Molecular weight used was 153.8. For calculation of the latent heat, we have,

$$A = 0.2358 \{ \text{antilog } 0.00026855t + \text{antilog } (0.7970507 - 0.00402434t) \},$$

where $t = t°$ C, a less satisfactory form of the equation than the one usually adopted.

Stannic Chloride. See Table 19. Data from Jour. Chem. Soc. 1891, p. 911; except density of the vapor at 0° which is

theoretical, the molecular weight used being 260.8. For calculating the latent heat, we have,

$$A = \text{antilog } (\bar{1}.3282379 + 0.00026212t) + \text{antilog } (0.2481708 - 0.00368282t)$$

where $t = t°$ C.

Water. See Table 18. See Phil. Trans. 1892, p. 107. Vapor pressures, 0° to 100° C, are Broch's calculations from Regnault's measurements, and other values are from Ramsay and Young. Density of the liquid, 0° to 100° C are from values in Landolt and Bornstein's tables, p. 39, and 100° to 270° C are from Ramsay and Young. Density of vapor, 0° to 210° C are as given by Ramsay and Young from Regnault's heats of vaporization, and 230° to 270° are "recalculated" values from their own measurements. Latent heats, 0° to 230° C are from Regnault, and 240° to 270° C were calculated by the author from the formula,

$$A = \text{antilog } (0.1416514 - 0.005950708t) + \text{antilog } (0.13884017 - 0.001656138t)$$

where $t = t°$ C + 20, the constants used for Biot's formula being given by Regnault.

Methyl Alcohol. See Table 19. Data from Phil. Trans. 1887A, p. 313; except density of liquid at 0° C from Dittmar and Fawsitt, and at 10° C average value of 0° and 20°. Inadvertently the observed pressures were used for the calculation of E_z, but the difference thus made is never more than 0.1 to 0.2 calorie, and the error thus introduced into the constant of equation 2 could never exceed one-tenth of one per cent.

Ethyl Alcohol. See Table 20. Data from Phil. Trans. 1886A, p. 123; except vapor pressure at 241°, 242°, and 242.5° C (calculated from Biot's formula); density of liquid 0° to 30° and at 100° Mendelejeff, 40° to 80° from Kopp's formula, and at 90° C estimated value.

Propyl Alcohol. See Table 21. Data from Phil. Trans. 1889A, p. 137. Observed vapor pressures were used to calcu-

late E_1. Density at 0° C is theoretical, the molecular weight used being 60.06.

Acetic Acid. See Table 22. Data from Jour. Chem. Soc. 49, 1886, p. 790, and in 1891. Vol. 59. p. 903, preference being given in all cases to the later measurements. For calculating the latent heat, we have,

$$A = \text{antilog } (\bar{1}.9257964 - 0.00149898t) + \text{antilog } (\bar{1}.1390566 - 0.0130424t),$$

where $t = t°\ C - 120$.

APPLICATION OF THE THEORY.

For details of the calculations involved the appended tables, 2 to 22, must be consulted. A summary of the results obtained for the constant by the use of the equation $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant}$, is given below in Table 1. Certain mean values of this constant somewhat arbitrarily chosen are given at the top of each column. All results not in agreement with this mean value of the constant by as much as two per cent. are in italics.

Since from 0° C to within 10° of the critical temperature eleven of the substances show altogether, out of two hundred and seventeen observations, only two divergences greater than two per cent. from the average values, it is clearly evident that the relation given by the equation cannot possibly be accidental. But *is the relation in these and in the other cases as accurate as the excellent experimental data will permit?* Only by such an agreement could the theory be finally established. To answer this question we must examine the manner and extent to which errors in the observations will affect the constant.

A cursory examination of the equation $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant}$ would make it appear that as the critical temperature is

approached and d approaches D in value, the diminishing difference of their respective cube roots would enormously increase the proportional errors of the observations. This is, however, not the case. Substituting for L its value from equation 4 and for E, its value from equation 1, we have,

$$[11] \qquad \frac{0.0_431833\,(V-v)\left(\frac{\delta P}{\delta T}\,T-P\right)}{\sqrt[3]{d}-\sqrt[3]{D}} = \text{constant}.$$

Next putting $d = 1/v$ and $D = 1/V$, and simplifying, we get,

$$[12] \quad 0.0_431833\,(Vv^{1/3}+V^{2/3}v^{2/3}+V^{1/3}v)\left(\frac{\delta P}{\delta T}\,T-P\right) = \text{con}.$$

On inspection of the factor, $Vv^{1/3}+V^{2/3}v^{2/3}+V^{1/3}v$, we see:

1. That errors of observation occurring in the *density of the liquid* have at low temperatures little effect on the constant, but as the critical temperature is approached and v approaches V in value, a percentage error in the density of the liquid will cause about ⅔ of the same percentage error in the constant.

2. That errors of observation occurring in the *density of the vapor* cause at low temperatures about the same percentage errors in the constant, but as V approaches v the percentage error caused in the constant is decreased to about ⅔ of the error of the observation.

To determine the error caused by an error in the vapor pressure, we transform equation 12 into the form

$$[13] \qquad \frac{\delta P}{\delta T}\,T-P = \frac{\text{Constant}}{0.0_431833\,(Vv^{1/3}+V^{2/3}v^{2/3}+V^{1/3}v)}.$$

The right-hand side of the equation is very small at low temperatures, but increases with rise of temperature until as the critical temperature is approached the function of the volumes approaches $3V^{1/3}$.

The relative magnitude of the terms on the left-hand side of the equation must be considered. Taking water at 0° C as

typical of a low vapor pressure (that it is typical will be seen if other substances are examined), we have $\frac{\delta P}{\delta T} = 0.329$, $T = 273$, $P = 4.600$, $V = 211131$, $v = 1$, and the equation takes the form $0.329 \times 273 - 4.600 = \frac{\text{Constant}}{0.0_4 31833 \times 213737}$. Since $0.329 \times 273 = 89.80$, the influence upon the constant of an error in the vapor pressure is relatively very small. T may be assumed correct, and the determining error therefore rests with the $\frac{\delta P}{\delta T}$. It is exceedingly important to note that while an error of 0.01 millimeter in the vapor pressure is an error of only *two-tenths of one per cent.* in that observation, yet if the same error exists in the $\frac{\delta P}{\delta T}$ the error so caused in the constant is *three per cent.*

For high vapor pressure considering water at 270° C (also a typical case) we have $\frac{\delta P}{\delta T} = 614$, $T = 543$, $P = 40570$ (from Biot's formula as given by Regnault), and the equation takes the form $614 \times 543 - 40570 =$ etc. And since $614 \times 573 = 351800$, it again appears that an error in the pressure produces only a very greatly diminished proportional error in the constant. It is again important to note that while an error of 20 millimetres in the pressure means an error of only *0.05 of one per cent.* in that measurement, yet this error occurring in the $\frac{\delta P}{\delta T}$ would produce an error of *more than three per cent* in that constant.

The function $\frac{\delta P}{\delta T}$ was obtained from Biot's formula (see equation 5). Biot's formula has stood the most severe tests, and I do not believe the accuracy of that formula *per se* can

now be questioned.[1] But it is a purely empirical formula *fitted* to the observations. It represents a curve and primarily is but a more refined method of drawing a curve through the observations. For all points along the line of this curve one is guided by the observations on *either* side until the ends of the curve are approached. But as the ends of the curve are approached one has to be guided more and more by the trend of the curve already established. That is, along interior portions of the curve individual errors in the measurement of the pressure are smoothed out and Biot's formula is far more accurate than the individual measurements, but at the ends of the curve this smoothing is necessarily far more imperfect and Biot's formula cannot give greatly more accurate results than the individual observations. (The fact that the constants for the formula are mathematically calculated makes this observation of course none the less true.)

Individual observations of vapor pressure could not be used to obtain a correct idea of the $\frac{\delta P}{\delta T}$ *because an error in these observations is multiplied proportionately anywhere from ten to seventy times in the* $\frac{\delta P}{\delta T}$. The method adopted will keep this enormous multiplication of error from being greatly apparent, except as either end of the Biot formula curve is approached. But throughout the entire range of the observations it is doubtless this multiplication of error in the $\frac{\delta P}{\delta T}$ that is most often responsible for the variation in the constant.

Many illustrations taken directly from the measurements enforcing the above remarks might be given, but attention will only be called to the case of water. Ramsay and

[1] See Ramsay and Young. Phil. Trans. 1887A, p. 89.

Young's observations of the vapor pressure of water are in beautiful accord (0° to 230° C) with the Regnault-Biot formula, whose results they quote. But when this formula is forced past the temperature (230° C) for which it was calculated, an error in the trend $\frac{\delta P}{\delta T}$ of the curve is at once apparent.[1] This error could neither have been suspected nor provided for, had either set of observations below 230° C been used to calculate the formula.

In this connection Prof. Young calls my attention to Broch's calculations of the vapor pressure of water, 0° to 100° C. Broch used the formula,

$$P = A\,10^{\frac{bt + ct^2 + dt^3 + et^4 + ft^5}{1 + at}},$$

and made exceedingly careful and laborious calculations. But unfortunately in obtaining his constants he used Regnault's data from —32° to 100° and the vapor pressures at the lower temperatures were for the most part those of ice, not water. Hence, remarks Prof. Young: "It is interesting to notice that below 0° his calculated pressures are with trifling exceptions, higher than the vapor pressures of *ice* observed by Regnault—a striking proof, if such were needed, that the vapor pressures of water are really higher than those of ice at the same temperatures. Moreover, Broch makes the vapor pressure of water at 0° = 4.569, whereas the mean of Regnault's actual observations, 12 in number, is 4.608." Again at 100° C, Prof. Young points out that the trend of Broch's curve is certainly wrong, and in proof of this he sends, and kindly permits me to publish, the following calculations upon the vapor pressure of water, made some years ago but never published.

[1] See Phil. Trans. 1892A, p. 119.

Vapor Pressures of Water

Temperatures	From Regnault's curve	From Broch's formula	Δ
100°	760.00	760.00	0.00
120	1489.0	1544.7	55.7
150	3572.0	4244.3	672.3
200	11660.0	31861.0	20201.0
Corrected for latitude, etc. and normal degrees C.			
200°	11660.0	31839.0	20179.0
Preliminary constants before employment of method of least squares			
200°	11660.0	40547.0	28887.0

It surely cannot be necessary to give further illustrations of the fact that the trend of no empirical curve can be trustworthy near its end point.

In conclusion therefore:—

3. Errors of observation occurring in the vapor pressure will exert *per se* little effect upon the constant of formula 2.

4. Errors in the vapor pressure may cause greatly multiplied error in the constant by affecting Biot's formula used for the calculation of the $\frac{\delta P}{\delta T}$. This source of error will be greatly more apparent at the end points for which the Biot formula was calculated.

THE EVIDENCE FOR THE THEORY.

The measurements considered in calculating the constants, of which Table 1 gives a summary, include thirty-one substances, and cover a range of 290° in temperature. The foregoing discussion has shown that errors of observation may

often be multiplied and are always compounded in their effect upon this constant. To cover this range of temperature, the number of substances, and the variously compounded errors of observation in vapor pressure, vapor density, and density of the liquid, errors which may be multiplied in the calculation, it has seemed to me reasonable to pass without discussion all variations in the constant less than two per cent. from the mean values chosen and given at the top of each column. An agreement within two per cent. of this mean value we therefore consider satisfactory. All values not showing this agreement are in black faced type.

Excepting values within ten degrees of the critical temperature the eleven substances, ethyl, oxide, di-isopropyl, isopentane, normal pentane, normal hexane, normal heptane, normal octane, benzene, hexamethylene, fluo-benzene, and carbon tetrachloride, show out of *two hundred and seventeen* observations only *two* that are not within two per cent. of the mean value adopted for that particular substance. The two exceptions are normal octane at 0° C and ethyl oxide at 180° C, and both of these divergences, as well as those occurring within ten degrees of the critical temperature, are, as shown below, easily explained.

In six of the eleven substances above mentioned, the observations allowed the tests of the formula to be carried to within one degree of the critical temperature, and in the case of normal pentane to within 0.05 of that point, yet in no case is the divergence greater than ten per cent. from the mean value adopted for that substance. Nearing the critical temperature an inspection will show that an error in the vapor pressure will be multiplied proportionately some seventy times in the constant if the error likewise affects the $\frac{\delta P}{\delta T}$ and, as already explained (p. 93), at the end points of the Biot formula curve these errors do affect, to a considerable degree, the $\frac{\delta P}{\delta T}$.

The same explanation will hold for normal octane at 0° C.

For ether at 180° C reference to the original data shows that the Biot formula adopted differs from the observations sufficiently to account for the divergence, and it is but proper here to add that Prof. Young writes: "Above 180° the substance (ether) was heated with methyl salicylate which was not quite satisfactory. In later work quinoline was used."

I think it may be safely said that every error occurring in these eleven substances could be entirely eliminated by changes in Biot's formula, in no case affecting any vapor pressure so much as five-tenths of one per cent., and I therefore emphasize the fact that *the only divergences from the theory shown by these eleven substances are not errors of observation, primarily, but of calculation.*

It may be well to mention that of the 217 observations for these eleven substances, 152 are within 1 per cent. of the average value, and the 63 that are within 2 per cent. of that value group themselves more largely at those points where errors of calculation and observation would be the greatest.

These eleven substances. therefore, from 0° C to their critical temperature, show, it seems to the author, as perfect accord with the theory as the method and observations will permit.

Of the other substances, the following observations are not within two per cent. of the mean values given.

Di-isobutyl, 120° to 190° C, inclusive, shows a divergence amounting at the greatest to five per cent. from the mean value. This may be caused by an error in the vapor density, because $P\Delta V$ does not show a maximum value at 2000 mms pressure, and the same value at 5000 to 6000 mms as at 500 to 600 mms, as is the case with similar substances.

Prof. Young has very kindly examined for me his original notes and calculations upon di-isobutyl. The measurements and calculations were abundantly checked, and there would seem to be no chance for unusually large errors. He suggests

that if a lower mean value were adopted the errors would be shifted toward the end points of the curve.

The author would here remark that a theory by Crompton to which attention will be called in a following paper, seems to bear out this suggestion, but also points more strongly to the fact that di-isobutyl does not give the results that similar substances would lead one to expect.

Chlor-benzene, 240° to 270° inclusive, may easily be due to the wrong trend $\frac{\delta P}{\delta T}$ of the Biot formula at this, its end point.

Brom-benzene at 30° C. The error here is due to the Biot formula, as shown by the fact that at 100° C the constant, from a theoretically calculated density is correct.

At 160° and 170° C the error may be due to the measurement of the vapor density. Prof. Young writes: "The observed volumes of saturated vapor are generally much less accurate at low temperatures than at high, because by the method employed, a given error in reading would have much greater influence at the lower temperature." Also regarding brom-benzene Prof. Young says: "After heating in ordinary daylight at 180°, 190°, 200°, 'brom-benzene slightly acted on by mercury, small quantity of solid being formed, chiefly in form of minute needle-shaped crystals.' In a second series the brom-benzene was 'carefully shielded from the light, no crystals formed.' The volumes were read in the first series only—the quantity of liquid in the second being small—and the results do not seem to me so satisfactory as with the other substances examined."

Iodo-benzene at 190° to 210° C, inclusive, may be due to measurement of vapor density. Dr. Young writes: "In the case of iodo-benzene similar crystals (to those with brom-benzene) were found, although the substance was shielded from daylight. All readings had to be taken by gas light and are therefore less accurate than usual."

The tendency towards continually increasing values of the

constant with rise in temperature in the case of chlor-benzene, brom-benzene and iodo-bezene, may easily be without significance, for in the first mentioned the tendency is not marked, and in the last two the final values are not far from the probable true values as shown by the results at 30° and 100° C. On the other hand, they may indicate progressive changes commencing within the molecule, and the remarks of Dr. Young above given are significant.

Stannic chloride may be said to be in agreement with the theory from 0° C to 170° C, but the values from 100° to 280° continually decrease, and there is little doubt that the cause of the variation is operative from the first. I would call attention to the high specific heat per atom that we find in stannic chloride and the conclusion based on grounds having nothing to do with the present theory, drawn therefrom by the author,[1] viz: "A high specific heat per atom indicates that the potential energy of the atoms is being rapidly increased and that the molecule is approaching the point of dissociation."

Prof. Young writes: "Stannic chloride spoils the surface of mercury even at low temperatures and special methods had to be used throughout. The accuracy is certainly not so great as with most of the other substances, but this will not, I think, explain the regular fall in the value of the constant."

Water shows divergence 0° to 30° C and at 270° C. Both may be explained by the multiplication of error through the $\frac{\delta P}{\delta T}$ at the end points of the Biot formula curve. Ramsay and Young's observations of the vapor pressures at 230° to 270° are in themselves rather conclusive evidence that the trouble at 270° C rests with the Regnault-Biot formula.[2]

See also remarks on page 94. The measurements of Grif-

[1] Jour. Elisha Mitchell Scientific Soc. Vol. 18.

[2] See Phil. Trans. **1892A**, p. 112.

fiths would indicate that the divergence at the lower temperatures is but partly due to the vapor pressure used.

The divergence in ethyl alcohol at 0° C is probably due to its being the end point of Biot formula used.

Methyl alcohol, 210° to 238.5° C, ethyl alcohol, 190° to 242.5° C, and propyl alcohol, 120° to 260°, evidently should be grouped together. They are associated substances, as was water, and the theory was not expected to hold for associated substances, because the molecules may not be evenly distributed, the molecules are of different kinds, and the number of molecules changes with changing temperature. The fact that the theory does hold, to a very considerable degree, for these substances also, is significant, and points strongly to the conclusion that the cause of the molecular association in these substances must be the attraction which we are discussing and not some other attraction such as we might denote by the term chemical affinity. And the fact that these associated substances do not agree even more closely with the theory may be entirely due to the supposition embraced by the formula that the molecules are uniformly distributed throughout the space occupied by them—a supposition probadly untrue for associated snbstances.

Bearing in mind the comments above, we conclude that the divergences shown by di-isobutyl, chlor-benzene, brom-benzene, iodo-benzene, and water, all occur at such points and are of such magnitude (none greater than 5.4 per cent.) that they may easily be due to errors of observation, or the multiplication of such errors by the calculations. Stannic chloride fails to agree with the theory. Water, methyl, ethyl, and propyl alcohols and acetic acid are associated substances to which the theory is not applicable *a priori*, and yet these substances, acetic acid excepted, appear within limits to agree with the theory.

In conclusion, to prevent further misapprehension, I would notice a review by Mr. G. N. Lewis[1] of the former paper on

[1] Jour. Am, Chem. Soc. 3, 107 (1903).

this subject. This paper presents additional evidence in favor of the theory, and it is the intention of the author to extend the work to the ten esters for which measurements have been made by Prof. Young. The "other assumptions of doubtful validity" upon which the present theory is based, referred to in that review, were mentioned in the original paper as they are in this (here they are numbered, however, so that he who runs may read), without attempt at proof. True equations are seldom deduced from wrong assumptions, and if we can establish the truth of the equation the assumptions will probably be admitted by those who now doubt their truth. All of the assumptions made, except possibly the law of attraction assumed, are, we are inclined to believe, regarded favorably by scientists on other grounds. Concerning the statement made in that review that "the author does not point out the simple relations between the densities of vapor and liquid, and the difference in their specific heats, which would be the direct consequence of his equations," we would say that we are of course aware that the equations that we have deduced can be combined with certain other thermodynamical, empirical and rational equations, so as to produce certain relations. (See for instance, equation 13 of this paper, which equation is similar to the relation, $p = bt - a$, of Professors Ramsay and Young.) The theory itself here given is capable of further direct and very promising application. The author hopes shortly to complete and publish a paper calling attention to some of these extensions of the theory.

For the measurements used we are indebted almost entirely to the labors of Profs. Ramsay and Young, and Prof. Young. After months of laborious acquaintance with these measurements we cannot conclude this paper without giving expression to the sincere admiration excited by the accuracy and completeness of the data they have furnished. And we would express a thanks, heartfelt, and echoed doubtless by hundreds of workers elsewhere, for their labors.

We wish further to express our thanks to Prof. Young for some unpublished details of the measurements and for comment upon the work, and we have taken the liberty of making in this paper some extracts from his letters.

SUMMARY.

1. The equation, $\frac{L - E_c}{\sqrt[3]{d} - \sqrt[3]{D}} = constant$ was deduced for the purpose of testing the assumption that the attraction between the molecules of any particular substance obeyed the law of gravitation, i. e., varied directly as the product of the masses, inversely as the square of their distance apart, and does not vary with the temperature.

2. Twenty-one substances were examined. Of these, eleven: ethyl oxide, di-isopropyl, isopentane, normal pentane, normal hexane, normal heptane, normal octane, benzene, hexamethylene, fluo-benzene, and carbon tetrachloride were, from 0° C to their critical temperature, making allowance for errors of observation and the multiplication of such errors in the calculation, in reasonably perfect agreement with the deduced equation. The divergences in di-isobutyl, chlor-benzene, brom-benzene, iodo-benzene, and water, all occur at such points and are of such magnitude that they may easily be due to the errors of observation (or the multiplication of such errors in the calculation). Stannic chloride failed to agree with the equation.

3. To the associated substances water, methyl, ethyl, and propyl alcohols, and acetic acid, the equation was not supposed applicable; but within wide limits the agreement of these substances, acetic acid excepted, is such as to suggest the conclusion that the molecular association with which we are there dealing is caused by the molecular attraction whose law we are considering.

TABLE I.

Temperature.	Ethyl oxide	Di-iso-propyl	Di-iso-butyl	Iso-pentane	Normal pentane	Normal hexane	Normal heptane	Normal octane	Benzene	Hexa-methylene
Mean value	104.4	98.0	88.7	105.4	109.0	101.7	98.4	92.85	109.5	103.6
0°	106.5	97.8	89.1	107.2	111.1	103.6	99.6	**97.5**	109.3	102.6
10	105.6	------	------	104.8	------	------	------	------	------	------
20	104.4	------	------	104.5	------	------	------	------	------	------
30	103.9	------	------	104.1	107.6	------	------	------	------	------
40	103.5	------	------	104.3	108.5	------	------	------	------	------
50	103.4	98.6	------	104.5	109.3	------	------	------	------	------
60	103.4	98.7	------	104.7	109.5	102.4	------	------	------	------
70	103.5	99.0	------	104.6	109.6	102.7	100.3	------	------	------
80	103.5	98.4	------	105.2	109.7	103.0	99.4	------	107.8	------
90	103.9	98.2	90.4	105.5	109.9	103.0	99.1	------	107.8	105.6
100	103.5	97.8	88.7	105.8	109.9	103.3	99.0	------	108.1	104.8
110	104.7	97.4	87.0	106.0	110.4	103.7	98.9	------	108.3	104.1
120	104.8	97.6	**85.3**	106.3	111.1	103.6	98.3	91.2	108.6	103.3
130	104.9	97.7	**85.0**	106.5	111.0	103.5	97.8	91.4	108.8	102.5
140	105.5	97.7	**84.9**	106.7	110.5	103.2	97.5	91.8	109.1	102.1
150	105.3	99.7	**84.6**	106.9	110.5	103.1	97.2	92.1	109.4	102.2
160	104.4	97.7	**85.1**	106.7	110.3	102.5	97.5	92.8	109.5	102.7
170	103.0	97.7	**85.7**	105.5	110.3	102.4	97.7	92.8	109.8	103.1
180	**101.0**	98.0	**86.2**	103.4	109.3	102.6	98.5	92.9	110.0	103.4
190	106.3	98.1	**86.8**	{187.4° **96.6**	**106.3**	102.8	98.9	93.1	110.4	102.9
200	{193° **114.5**	98.1	87.0	------	{197.15° **98.8**	102.7	99.2	93.3	110.5	103.1
210	------	97.3	87.3	------	------	102.1	99.7	93.9	110.5	103.5
220	------	**94.8**	87.9	------	------	101.1	99.7	93.6	110.7	104.2
230	------	{225° **92.0**	88.6	------	------	**98.0**	99.8	93.9	111.1	104.6
240	------	------	89.0	------	------	{234° **94.2**	99.8	93.7	110.6	104.6
250	------	------	89.5	------	------	------	99.3	94.2	110.3	104.9
260	------	------	89.4	------	------	------	96.6	94.6	110.0	104.7
270	------	------	87.6	------	------	------	{266.5° **90.8**	94.3	110.0	103.4
280	------	------	{274° **88.4**	------	------	------	------	93.4	107.8	{279° **98.1**
290	------	------	------	------	------	------	------	91.0	------	------
Critic'l temp.	194°	227.35°	276.8°	187.8°	197.2°	234.8°	266.9°	296.2°	288.5°	279.95°

TABLE 1.—*Continued.*

Temperature	Fluobenzene	Chlorbenzene	Bromobenzene	Iodobenzene	Carbon tetrachloride	Stannic chloride	Water	Methyl alcohol	Ethyl alcohol	Propyl alcohol	Acetic acid
Mean value	85.7	81.0	56.1	44.2	44.3	26.0	556.0	302.3	240.1	199.2	----
0	84.6	81.6	----	----	43.53	26.20	**585.7**	304.7	**232.8**	208.1	----
10	----	----	----	----	----	----	**580.1**	306.0	235.4	----	----
20	----	----	----	----	----	----	**575.2**	306.6	237.4	----	81.3
30	----	----	**58.74**	44.99	----	----	**570.7**	307.9	239.9	----	83.8
40	----	----	----	----	----	----	566.6	307.4	241.7	----	86.1
50	----	----	----	----	----	----	563.0	308.3	242.4	----	87.8
60	----	----	----	----	----	----	559.9	308.0	243.6	----	**90.4**
70	----	----	----	----	----	----	556.9	308.1	244.1	----	92.2
80	86.8	----	----	----	----	----	554.5	307.8	244.9	199.9	94.7
90	87.2	----	----	----	43.52	----	552.4	307.1	244.6	199.2	96.4
100	86.9	----	56 93	44.65	43 58	26. 45	550.6	306.3	244.8	197.6	98.5
110	86.7	----	----	----	43.58	26.34	549.5	306.0	242.7	196.2	100.7
120	86.3	----	----	----	43.64	26.24	548.6	305.4	242.1	**193.6**	104.3
130	85.7	79.5	----	----	43.67	26.16	547.8	304.5	241.0	191.3	104.9
140	85.0	80.3	----	----	43.79	26.00	547.6	304.1	241.0	191.1	105.5
150	84.6	81.1	----	----	43.79	25.82	547 3	301.3	241.1	187.8	106.6
160	84.7	80.8	**54.09**	----	43.83	25.68	547 8	303.1	239.8	**185.6**	107.9
170	84.7	81.3	**54.48**	----	43.86	25.46	548.7	302.3	238.2	184.1	111.7
180	84.7	81.2	54.98	----	43.92	**25.13**	**550.4**	300.9	236.5	**182.7**	111.3
190	84.8	81.3	55.21	**41.87**	44.00	**24.84**	551.8	300.8	**233.3**	**180.4**	113.3
200	84.7	81.3	55.45	**42.06**	44.16	**24.68**	553.9	299.3	**230.0**	**178.6**	115.4
210	85.1	81.6	55.91	**43.06**	44.34	**24.45**	556.4	**295.4**	229.3	**176.6**	117.5
220	85.5	81.8	55.87	43.64	44.55	**24.20**	559.1	**287.6**	**223.0**	**173.2**	119.1
230	85.8	82.3	56.25	45.73	44.76	**23.96**	563.0	**276.5**	219.7	**168.8**	121.5
240	86.2	**83.1**	56.19	44.03	44.94	**23.63**	553.6	(238 5° / **259.4**	**209.2**	164.1	124.1
250	86.6	**83.6**	56.44	44.38	45.16	**23.35**	551.0	----	(242.5° / **197.2**	**160 2**	126.4
260	86.8	**84.3**	56 92	44.68	44.99	**22.98**	544.9	----	----	157.0	128.4
270	86.3	**84.9**	57.15	45.10	44.47	**22.47**	**535 5**	----	----	----	130.0
280	84.7	----	----	----	43.90	**22.15**	----	----	----	----	131.5
290	----	----	----	----	----	----	----	----	----	----	131.2
Crit'l temp	286.55°	360.7°	397°	448°	283.15°	318.7°	365°	240°	243.6°	263.7°	321.65°

TABLE 2

Ethyl Oxide.

Temperature	Pressure.	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	184.90	0.7362	0.0006270	93.27	7.11	86.16	0.8091	106.5
10	291.78	0.7248	0.001264	90.77	7.33	83.44	0.7901	105.6
20	442.36	0.7135	0.001870	87.90	7.50	80.40	0.7704	104.4
30	647.93	0.7019	0.002677	85.60	7.68	77.92	0.7499	103.9
40	921.18	0.6894	0.003781	83.18	7.82	75.36	0.7283	103.5
50	1276.11	0.6764	0.005079	80.95	7.94	73.01	0.7059	103.4
60	1728.13	0.6658	0.006771	78.84	8.05	70.79	0.6840	103.4
70	2293.91	0.6582	0.008920	76.42	8.07	68.35	0.6603	103.5
80	2991.40	0.6402	0.01155	73.95	8.10	65.85	0.6359	103.5
90	3839.71	0.6250	0.01477	71.39	8.08	63.31	0.6096	103.9
100	4859.01	0.6105	0.01867	68 35	8.02	60.33	0 5830	103.5
110	6070.38	0.5942	0.02349	65.98	7.91	58 07	0.5543	104.7
120	7495.73	0.5764	0.02934	62.63	7.72	54.91	0.5238	104.8
130	9157.42	0.5580	0.03638	59.11	7.49	51.62	0.4919	104.9
140	11078.2	0.5385	0.04488	55.52	7.21	48.31	0.4582	105.5
150	13281.0	0.5179	0.05551	51.18	6.80	44 38	0.4216	105.3
160	15788.1	0.4947	0.06911	45.99	6.25	39.74	0.3805	104.4
170	18622.2	0.4658	0.08731	39.69	5.51	34.18	0.3315	103.0
180	21804.3	0.4268	0.1135	31.58	4.49	27.09	0.2687	101.0)
185	23532.4	0.4018	0.1320	26.78	3.82	22.96	0.2287	100.4)
190	25355.1	0.3603	0.1620	20.90	2.79	18.11	0.1704	106.3
182	26111.2	0.3448	0.1826	17.10	2.14	14.96	0.1339	111.6)
193	26495.0	0.3300	0.2012	13.67	1.67	12.03	0.1051	114.5)

TABLE 3

Di-isopropyl

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.\ T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	76.05	0.6795	0.0003840	54.05	1.57468	85.11	6.30	78.81	0.8065	97.81
50	584.1	0.6338	0.002551	73.64	1.06573	78.47	7.26	71.21	0.7224	98.57
60	806.8	0.6243	0.003448	77.49	0.99238	76.90	7.41	69.49	0.7036	98.75
70	1090.3	0.6144	0.004566	81.29	0.92634	75.30	7.54	67.76	0.6842	99.03
80	1444.8	0.6039	0.006006	84.05	0.86685	72.86	7.58	65.28	0.6635	98.39
90	1880.9	0.5931	0.007752	86.90	0.81327	70.67	7.62	63.05	0.6423	98.16
100	2409.7	0.5821	0.009901	89.26	0.76498	68.28	7.61	60.67	0.6203	97.81
110	3043.0	0.5708	0.01250	91.15	0.72144	65.76	7.58	58.18	0.5974	97.38
120	3793.2	0.5589	0.01555	93.18	0.68219	63.57	7.54	56.03	0.5741	97.60
130	4673.0	0.5464	0.01923	94.54	0.64677	61.15	7.47	53.68	0.5496	97.69
140	5697.0	0.5334	0.02358	95.28	0.61479	58.58	7.34	51.24	0.5242	97.75
150	6879.0	0.5197	0.02825	97.46	0.58592	57.10	7.33	49.77	0.4994	99.67
160	8234.0	0.5049	0.03521	94.13	0.55982	52.70	6.92	45.78	0.4685	97.72
170	9781.0	0.4885	0.04292	92.05	0.53623	49.36	6.61	42.75	0.4375	97.71
180	11536.0	0.4705	0.05216	89.06	0.51488	45.86	6.26	39.60	0.4042	97.98
190	13519.0	0.4508	0.06361	84.50	0.49555	41.87	5.81	36.06	0.3676	98.09
200	15752.0	0.4274	0.07831	77.71	0.47803	37.15	5.23	31.92	0.3255	98.07
210	18258.0	0.3988	0.09862	67.28	0.46213	31.09	4.43	26.66	0.2741	97.27
216	19905.0	0.3758	0.1163	57.80	0.45331	26.20	3.76	22.44	0.2335	96.10
220	21062.0	0.3565	0.1321	49.45	0.44770	22.14	3.19	18.95	0.1998	94.84)
225	22585.0	0.3198	0.1649	33.04	0.44099	14.57	2.11	12.46	0.1355	91.96)

TABLE 4

Di-isobutyl

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.\ T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	7.11	0.7102	0.00004762	40.76	1.98712	80.99	4.75	76.24	0.8560	89.06
90	425.6	0.6328	0.002174	70.82	1.01836	72.12	6.21	65.91	0.7290	90.41
100	581.1	0.6236	0.002967	72.70	0.95256	69.25	6.20	63.05	0.7106	88.73
110	777.9	0.6143	0.003984	74.30	0.89276	66.33	6.17	60.16	0.6916	86.98
120	1022.6	0.6046	0.005296	76.08	0.83846	63.79	6.16	57.63	0.6720	85.76)
130	1322.5	0.5945	0.006757	77.98	0.78921	61.54	6.16	55.38	0.6517	84.97)
140	1684.9	0.5841	0.008532	80.37	0.74460	59.84	6.19	53.65	0.6316	84.94)
150	2118.2	0.5732	0.01072	82.06	0.70425	57.79	6.17	51.62	0.6102	84.59)
160	2630.6	0.5620	0.01319	84.30	0.66783	56.30	6.19	50.11	0.5889	85.09)
170	3231.3	0.5508	0.01610	86.30	0.63500	54.80	6.20	48.60	0.5670	85 71)
180	3930.2	0.5383	0.01957	87.61	0.60549	53.05	6.15	46.90	0.5440	86.21)
190	4738.0	0.5255	0.02370	88.39	0.57903	51.18	6.08	45.10	0.5197	86.78)
200	5666.5	0.5117	0.02874	87.93	0.55539	48.83	5.92	42.91	0.4985	86.96
210	6729.5	0.4970	0.03484	86.80	0.53433	46.38	5.72	40.66	0.4655	87.34
220	7941.0	0.4810	0.04202	84.94	0.51566	43.80	5.48	38.32	0.4358	87.93
230	9319.0	0.4633	0.05094	81.89	0.49918	40.88	5.18	35.70	0.4081	88.56
240	10883.0	0.4434	0.06223	77.10	0.48474	37.37	4.78	32.59	0.3663	88.97
250	12654.0	0.4199	0.07680	70.40	0.47218	33.24	4.28	28.96	0.3237	89.47
260	14660.0	0.3912	0.09699	60.55	0.46135	27.93	3.62	24.31	0.2719	89.41
270	16929.0	0.3482	0.1321	43.21	0.45213	19.54	2.53	17.01	0.1942	87.58
274	18006,0	0.3187	0.1572	31.72	0.44887	14.24	1.85	12.39	0.1434	86.40)

TABLE 5

Isopentane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p \Delta v. T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	257.74	0.6392	0.001090	64.43	1.37910	88.86	7.51	81.35	0.7585	107.2
10	390.52	0.6295	0.001646	66.96	1.26846	84.93	7.53	77.40	0.7389	104.8
20	572.59	0.6196	0.002358	70.88	1.16990	82.91	7.70	75.21	0.7194	104.5
30	815.34	0.6092	0.003300	74.45	1.08206	80.55	7.82	72.73	0 6988	104 1
40	1131.1	0.5988	0.004480	78.41	1.00375	78.69	7.97	70.72	0.6781	104.3
50	1533.2	0 5881	0.005967	82.14	0.93390	76.71	8.09	68.62	0.6564	104.5
60	2035.6	0.5769	0.007819	85.55	0.87157	74.56	8.18	66.38	0.6340	104.7
70	2653.0	0.5656	0.01011	88.36	0.81591	72.09	8.20	63.89	0.6107	104.6
80	3400.8	0.5540	0.01284	91.36	0.76618	70.00	8.24	61.76	0.5871	105.2
90	4295.6	0.5413	0.01617	93.54	0.72171	67.51	8.20	59.31	0.5621	105.5
100	5354.5	0.5278	0.02022	95.00	0.68194	64.78	8.11	56.67	0.5357	105.8
110	6596.1	0.5140	0.02513	95.64	0.64631	61.81	7.95	53.86	0.5081	106.0
120	8039.9	0.4991	0.03106	95.42	0.61439	58.62	7.73	50.89	0.4788	106.3
130	9706.7	0.4826	0.03831	94.02	0.58574	55.07	7.43	47.64	0.4473	106.5
140	11620.0	0.4642	0.04728	91.19	0.56002	51.07	7.03	44.04	0.4127	106.7
150	13804.0	0.4445	0.05834	86.92	0.53689	46.67	6.54	40.13	0.3754	106.9
160	16285.0	0.4206	0.07289	79.98	0.51605	41.27	5.88	35.39	0.3316	106.7
170	19094.0	0.3914	0.09337	68.93	0.49728	34.28	4.95	29.33	0.2778	105.5
176	20950.0	0.3694	0.1101	59.90	0.48690	29 17	4.25	24.92	0,2382	104.6
180	22262.0	0.3498	0.1258	51.33	0.48031	24.65	3.61	21.04	0.2035	103.4
183	23288.0	0.3311	0.1418	42.80	0.47555	20.35	2.99	17.36	0.1708	101.9)
185	23992.0	0.3142	0.1574	34.86	0.47245	16.47	2.42	14.05	0.1399	100.4)
186	24350.0	0.3028	0.1676	29.76	0.47093	14.01	2.06	11.95	0.1201	99.5)
187	24713.0	0.2857	0.1833	22.22	0.46942	10.43	1.54	8.89	0.0905	98.2)
187.4	24880.0	0.2761	0.1951	17.21	0.46882	8.07	1.19	6.88	0.0712	96.6)

TABLE 6

Normal Pentane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p \Delta v. T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	183.40	0.6454	0.0007756	64.48	1.44799	93.36	7.51	85.85	0.7723	111.1
30	613.9	0.6165	0.002475	74.84	1.13456	84.91	7 86	77,05	0.7158	107.6
40	865.3	0.6062	0.003390	79.47	1.05221	83.63	8.08	75.55	0.6961	108,5
50	1190.2	0.5957	0.004545	83.91	0.97878	82.13	8.27	73.86	0.6758	109.3
60	1601.8	0.5850	0.006024	87.65	0.91324	80.04	8.38	71.66	0.6544	109.5
70	2114.0	0.5739	0.007868	90.93	0.85466	77.71	8.44	69.27	0.6321	109.6
80	2742.1	0.5624	0.01013	93.86	0.80221	75.30	8.46	66.84	0 6091	109.7
90	3501.5	0.5503	0.01289	96.30	0.75519	72.73	8.45	64.28	0 5850	109.9
100	4409.1	0.5378	0.01627	97.99	0.71297	69.87	8.36	61.51	0.5598	109.9
110	5482.5	0.5248	0.02026	99.62	0.67497	67.24	8.28	58.96	0.5340	110.4
120	6740.5	0.5107	0.02505	100.65	0.64073	64.48	8.15	56.33	0.5068	111.1
130	8203.0	0.4956	0.03106	99.78	0.60979	60.85	7.88	52.97	0.4770	111.0
140	9890.0	0.4787	0.03861	97.26	0.58177	56.58	7.50	49.08	0 4442	110.5
150	11826.0	0.4604	0.04762	94.16	0.55636	52.39	7.09	45.30	0.4097	110.5
160	14032.0	0.4394	0.05910	88.94	0.53323	47.42	6.53	40.89	0.3707	110.3
170	16535.0	0.4161	0.07347	82.13	0.51213	42.06	5.90	36.16	0.3278	110.3
180	19362.0	0.3867	0.09354	71.66	0.49284	35.01	4.99	30.02	0.2746	109.3
186	21225.0	0.3643	0.1109	61.14	0.48205	29.47	4.24	25.23	0.2337	108.0
190	22540.0	0.3445	0.1269	51.95	0.47516	24.68	3.57	21.11	0.1985	106.3)
193	23566.0	0.3253	0.1441	42.50	0.47014	19.98	2.90	17.08	0.1634	104.5)
195	24271.0	0.3065	0.1609	33.54	0.46685	15.66	2.28	13.38	0.1303	102.7)
196	24629.0	0.2915	0.1745	26.55	0.46524	12.35	1.80	10.55	0.1042	101.2)
196.5	24810.0	0.2809	0.1842	21.78	0.46443	10.12	1.48	8.64	0.0859	100.6)
197.0	24991.0	0.2640	0.2004	14.12	0.46363	6.55	0.96	5.59	0.0563	99.3)
197.1	25027.0	0.2560	0.2090	10.34	0.46347	4.79	0.70	4.09	0.0415	98.5)
197.15	25045.0	0.2472	0.2167	6.71	0.46339	3.11	0.45	2.66	0.0269	98.8)

TABLE 7

Normal Hexane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p\,\Delta v.\,T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
0°	44 92	0. 6770	0. 0002268	54. 05	1. 68307	90. 98	6. 30	84. 68	0. 8171	103. 6
60	567. 62	0. 6221	0. 00249	75. 68	1. 06787	80. 82	7. 23	73. 59	0. 7182	102. 4
70	784. 80	0. 6122	0. 00337	79. 51	0. 99598	79. 19	7. 38	71. 81	0. 6992	102. 7
80	1062. 0	0. 6022	0. 00446	83, 31	0. 93083	77. 55	7. 51	70. 04	0. 6799	103. 0
90	1409. 0	0. 5918	0. 00585	86. 61	0. 87180	75. 51	7. 60	67. 91	0. 6594	103. 0
100	1838. 0	0. 5814	0. 00752	90. 00	0. 81835	73. 65	7 68	65. 97	0. 6387	103. 3
110	2358. 0	0. 5703	0. 00952	93. 18	0 76998	71. 75	7. 74	64. 01	0. 6174	103. 7
120	2982. 0	0. 5588	0. 01200	95. 54	0. 72623	69. 38	7. 74	61. 64	0. 5947	103. 6
130	3723. 0	0. 5467	0. 01502	97. 24	0. 68669	66. 78	7. 68	59. 10	0. 5710	103. 5
140	4593. 0	0. 5343	0. 01862	98. 25	0. 65098	63. 96	7. 57	56. 39	0. 5464	103 2
150	5606. 0	0. 5207	0. 02299	98. 64	0. 61874	61. 03	7. 42	53. 61	0. 5201	103. 1
160	6778. 0	0. 5063	0. 02833	97. 73	0. 58968	57. 63	7. 18	50. 45	0. 4921	102. 5
170	8123. 0	0. 4913	0. 03472	96. 44	0. 56352	54. 34	6. 93	47. 41	0. 4629	102. 4
180	9659. 0	0. 4751	0. 04228	94. 31	0. 53998	50. 93	6 63	44. 30	0. 4319	102. 6
190	11407. 0	0. 4570	0. 05155	90. 89	0. 51888	47. 16	6. 25	40. 91	0. 3981	102. 8
200	13385. 0	0. 4365	0. 06329	85. 52	0. 49986	42. 75	5. 75	37. 00	0. 3601	102. 7
210	15619. 0	0. 4124	0. 07900	77. 23	0. 48289	37. 29	5. 09	32. 20	0. 3152	102. 1
220	18133. 0	0. 3809	0. 1011	64. 93	0. 46773	30. 87	4. 19	26. 18	0. 2590	101. 1
226	19788. 0	0. 3557	0. 1203	53. 97	0. 45943	24. 79	3. 46	21. 33	0. 2148	99. 3)
230	20957. 0	0. 3329	0. 1404	43. 43	0. 45421	19. 73	2. 75	16. 98	0 1732	98. 0)
233	21870. 0	0. 3040	0. 1658	30. 32	0. 45045	13. 66	1. 90	11. 76	0. 1230	95. 6)
234	22181. 0	0 2883	0. 1807	23. 24	0. 44923	10. 44	1. 46	8. 98	0. 0953	94. 2)

TABLE 8

Normal Heptane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.\,T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
0°	11. 45	0. 7005	0. 00006725	46. 46	1. 93423	89. 86	5. 42	84. 44	0. 8474	99. 6
70	302. 77	0. 6402	0. 001435	72. 17	1. 13368	81. 84	6. 70	75. 14	0. 7491	100. 3
80	427. 10	0. 6311	0. 001996	75. 22	1. 05722	79. 52	6. 78	72. 74	0. 7319	99. 4
90	588. 74	0. 6218	0. 002703	78. 66	0. 98784	77. 70	6. 90	70. 80	0. 7142	99. 1
100	794. 93	0. 6124	0. 003584	82. 13	0. 92493	75. 98	7. 01	68. 85	0. 6962	99. 0
110	1053. 3	0. 6027	0. 004692	85. 33	0. 86789	74. 06	7. 09	66. 97	0. 6773	98. 9
120	1372. 1	0. 5926	0. 006068	87. 95	0. 81624	71. 79	7. 12	64. 67	0. 6576	98. 3
130	1759. 9	0. 5821	0. 007752	90. 27	0. 76948	69. 46	7. 13	62. 33	0. 6371	97. 8
140	2226. 1	0. 5711	0. 009775	92. 39	0. 72719	67. 19	7. 12	60. 07	0. 6159	97. 5
150	2780. 4	0. 5598	0. 012222	94. 08	0. 68898	64. 81	7. 08	57. 73	0. 5939	97. 2
160	3433. 3	0. 5481	0. 01508	95. 87	0. 65447	62. 74	7. 05	55. 69	0. 5713	97. 5
170	4196. 0	0. 5359	0. 01848	97. 02	0. 62337	60. 48	6. 97	53. 51	0. 5479	97. 7
180	5080. 9	0. 5232	0. 02242	98. 30	0. 59536	58. 52	6. 90	51. 62	0. 5238	98. 5
190	6101. 3	0. 5096	0. 02717	98. 30	0. 57017	56. 05	6. 76	49. 29	0. 4982	98. 9
200	7271. 8	0. 4952	0. 03304	97. 14	0. 54757	53. 17	6. 54	46. 63	0. 4703	99. 2
210	8608. 6	0. 4793	0. 04005	95. 15	0. 52730	50. 17	6. 27	43. 90	0. 4405	99. 7
220	10130. 0	0. 4616	0. 04892	91. 25	0. 50919	46. 46	5. 89	40. 57	0. 4071	99. 7
230	11857. 0	0. 4414	0. 06002	85. 81	0. 49305	42. 31	5. 43	36. 88	0. 3698	99. 8
240	13811. 0	0. 4177	0. 07446	78. 24	0. 47869	37. 45	4. 85	32. 60	0. 3268	99. 8
250	16020. 0	0. 3877	0. 09461	67. 05	0. 46598	31. 25	4. 08	27. 17	0. 2735	99. 3
260	18511. 0	0. 3457	0. 1287	48. 15	0. 45475	21. 90	2. 88	19. 02	0. 1969	96. 6
264	19595. 0	0. 3166	0. 1538	35. 15	0. 45066	15. 84	2. 08	13. 76	0. 1458	94. 4)
266	20150. 0	0. 2907	0. 1778	23. 73	0. 44869	10. 65	1. 40	9. 25	0. 1001	92. 4)
266. 5	20300. 0	0. 2819	0. 1895	8. 97	0. 44821	8. 50	1. 12	7. 38	0. 0813	90. 8)

TABLE 9

Normal Octane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p\Delta v.T}{10^6}$	A	Latent heat.	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
0°	2.90	0.7185	0.00001942	40.77	2.1942	89.46	4.75	84.71	0.8688	97.50
120	649.3	0.6168	0.003300	76.91	0.91369	70.27	6.24	64.03	0.7023	91.17
130	859.4	0.6071	0.004292	80.16	0.85906	68.86	6.33	62.53	0.6842	91.39
140	1114.5	0.5973	0.005464	83.47	0.80944	67.56	6.43	61.13	0.6661	91.77
150	1426.9	0.5875	0.006897	86.50	0.76440	66.12	6.51	59.61	0.6471	92.12
160	1802.4	0.5772	0.008584	89.59	0.72354	64.82	6.58	58.24	0.6278	92.77
170	2249.0	0.5667	0.01065	91.74	0.68649	62.98	6.59	56.39	0.6075	92.82
180	2775.4	0.5556	0.01314	93.41	0.65293	60.99	6.56	54.43	0.5861	92.87
190	3390.7	0.5441	0.01608	94.82	0.62252	59.06	6.52	52.51	0.5640	93.10
200	4105.0	0.5317	0.01957	95.54	0.59501	56.87	6.43	50.44	0.5406	93.30
210	4928.9	0.5189	0.02364	96.17	0.57015	54.83	6.34	48.49	0.5166	93.86
220	5874.6	0.5053	0.02874	95.00	0.54769	52.03	6.13	45.90	0.4902	93.63
230	6955.0	0.4901	0.03484	93.41	0.52743	49.27	5.91	43.36	0.4618	93.90
240	8184.5	0.4732	0.04237	90.29	0.50918	45.97	5.60	40.37	0.4307	93.73
250	9578.8	0.4554	0.05118	86.87	0.49276	42.80	5.29	37.51	0.3981	94.22
260	11156.0	0.4364	0.06223	81.87	0.47802	39.14	4.89	34.25	0.3622	94.56
270	12937.0	0.4123	0.07716	73.96	0.46480	34.38	4.33	30.05	0.3186	94.32
280	14942.0	0.3818	0.09833	62.38	0.45298	28.26	3.59	24.67	0.2689	93.40
290	17198.0	0.3365	0.1346	43.18	0.44243	19.10	2.44	16.66	0.1831	91.00

TABLE 10

Benzene

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
0°	26.54	0.9001	0.0001215	107.05	6.95	100.10	0.9160	109.3
80	753.62	0.8145	0.002722	94.40	8.78	85.62	0.7943	107.8
90	1016.1	0.8041	0.003570	92.76	9.02	83.74	0.7771	107.8
100	1344.3	0.7927	0.004690	91.05	9.07	81.98	0.7581	108.1
110	1748.2	0.7809	0.006035	89.20	9.15	80.05	0.7388	108.3
120	2238.1	0.7692	0.007634	87.36	9.24	78.12	0.7194	108.6
130	2824.9	0.7568	0.009515	85.43	9.33	76.10	0.6994	108.8
140	3520.0	0.7440	0.01174	83.48	9.39	74.09	0.6789	109.1
150	4344.8	0.7310	0.01436	81.35	9.42	71.93	0.6577	109.4
160	5281.9	0.7185	0.01734	79.20	9.46	69.74	0.6368	109.5
170	6374.1	0.7043	0.02087	76.90	9.43	67.47	0.6144	109.8
180	7625.2	0.6906	0.02487	74.53	9.41	65.12	0.5920	110.0
190	9049.4	0.6758	0.02977	71.93	9.25	62.68	0.5676	110.4
200	10663.0	0.6605	0.03546	69.01	9.06	59.95	0.5424	110.5
210	12482.0	0.6432	0.04207	65.80	8.83	56.97	0.5154	110.5
220	14526.0	0.6255	0.05015	62.32	8.48	53.84	0.4864	110.7
230	16815.0	0.6065	0.06024	58.49	8.00	50.49	0.4545	111.1
240	19369.0	0.5851	0.07139	54.21	7.58	46.63	0.4216	110.6
250	22214.0	0.5609	0.08554	49.40	7.01	42.39	0.3841	110.3
260	25376.0	0.5328	0.1038	43.76	6.27	37.49	0.3407	110.0
270	28885.0	0.4984	0.1287	36.97	5.30	31.67	0.2880	110.0
280	32772.0	0.4514	0.1660	27.43	3.98	23.45	0.2175	107.8

TABLE 11

Hexamethylene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	27.85	0.7967	0.0001374	55.34	1.73860	96.22	6.45	89.77	0.8754	102.6
90	992.34	0.7106	0.003759	95.32	0.90396	86.17	8.36	77.81	0.7369	105.6
100	1306.8	0.7003	0.004902	98.77	0.84748	83.71	8.43	75.28	0.7181	104.8
110	1691.0	0.6898	0.006289	102.03	0.79610	81.23	8.48	72.75	0.6990	104.1
120	2155.4	0.6791	0.007968	105.01	0.74938	79.69	8.51	70.18	0.6793	103.3
130	2709.1	0.6680	0.01000	107.52	0.70695	76.01	8.49	67.52	0.6588	102.5
140	3362.0	0.6565	0.01238	110.11	0.66844	73.60	8.49	65.11	0.6378	102.1
150	4124.5	0.6448	0.01508	112.90	0.63349	71.52	8.49	63.03	0.6168	102.2
160	5007.3	0.6325	0.01818	115.78	0.60183	69.68	8.51	61.17	0.5955	102.7
170	6021.9	0.6200	0.02183	117.93	0.57314	67.59	8.47	59.12	0.5732	103.1
180	7199.9	0.6067	0.02625	119.05	0.54721	65.15	8.36	56.79	0.5494	103.4
190	8494.5	0.5926	0.03140	118.62	0.52377	62.13	8.15	53.98	0.5245	102.9
200	9980.2	0.5780	0.03738	118.11	0.50263	59.37	7.95	51.42	0.4986	103.1
210	11651.0	0.5626	0.04437	116.84	0.48358	56.50	7.70	48.80	0.4715	103.5
220	13526.0	0.5456	0.05249	114.82	0.46645	53.56	7.41	46.15	0.4427	104.2
230	15622.0	0.5271	0.06250	110.81	0.45107	49.98	7.01	42.97	0.4109	104.6
240	17961.0	0.5063	0.07496	104.65	0.43732	45.76	6.49	39.27	0.3754	104 6
250	20565.0	0.4820	0.09058	96.52	0.42504	41.02	5.87	35.15	0.3350	104.9
260	23461.0	0.4533	0.1111	84.91	0.41409	35.16	5.07	30.09	0.2874	104.7
270	26680.0	0.4125	0.1433	66.68	0.40441	26.72	3.87	22.85	0.2210	103.4
277	29140.0	0.3642	0.1855	42.31	0.39829	16.85	2.45	14.40	0 1438	100.1
279	29878.0	0.3393	0.2105	29.69	0.39664	11.78	1.71	10.07	0.1026	98.1

TABLE 12

Fluo-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	20.92	1.0465	0.0001179	48.43	1.80422	87.39	5.65	81.74	0.9662	84.60
80	645.98	0.9496	0.002885	78.79	1.01612	80.06	7.10	72.96	0.8405	86.80
90	879.73	0.9366	0.003831	83.03	0.95108	78.97	7.28	71.69	0.8219	87.22
100	1174.9	0.9233	0.005040	86.46	0.89163	77.09	7.38	69.71	0.8023	86.86
110	1541.3	0.9096	0.006515	89.97	0.83731	75.33	7.48	67.85	0.7821	86.75
120	1989.2	0.8955	0.008333	92.94	0.78772	73.21	7.53	65 68	0.7611	86.29
130	2529.5	0.8811	0.01055	95.49	0.74249	70.90	7.54	63.36	0.7394	85.69
140	3173.0	0.8665	0.01321	97.67	0.70128	68.50	7.53	60.97	0.7170	85.03
150	3931.4	0.8519	0.01634	99.78	0 66379	66.26	7.51	58.75	0.6942	84.63
160	4816.7	0.8363	0.01992	102.23	0.62970	64.37	7.51	56.86	0.6711	84.73
170	5841.6	0 8203	0.02413	104.08	0.59878	62.32	7.48	54.84	0.6471	84.74
180	7018.9	0.8037	0.02911	105.28	0.57076	60.09	7.40	52.69	0.6221	84.70
190	8363.5	0.7857	0.03496	105.84	0.54542	57.83	7.28	50.55	0.5958	84.85
200	9890.5	0.7671	0.04184	105.71	0.52257	55.24	7.11	48.13	0.5683	84.66
210	11617.0	0.7480	0.04968	105.43	0.50202	52.93	6.95	45.98	0.5401	85.09
220	13561.0	0.7265	0.05907	103.97	0.48356	50.28	6.71	43.57	0.5095	85.51
230	15745.0	0.7036	0.07037	101.30	0 46708	47.32	6.41	40.91	0.4766	85.84
240	18190.0	0.6789	0.08403	97.32	0.45241	44.03	6.04	38.00	0.4409	86.19
250	20924 0	0.6504	0.1008	91.70	0.43941	40.29	5.58	34.71	0.4010	86.58
260	23977.0	0.6163	0.1226	83.50	0.42796	35.74	5.09	30.75	0.3541	86.85
270	27384.0	0.5739	0.1535	70.96	0.41796	29.66	4.16	25.50	0.2956	86.26
280	31182.0	0.5133	0.2034	51.20	0.40928	20.95	2.95	18.00	0.2126	84.69

TABLE 13

Chlor-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
0°	2.56	1.1278	0.00001689	41.36	2.12075	87.72	4.82	82.90	1.0152	81.65
130	720.08	0.9836	0.003409	84.81	0.86978	78.77	6.70	67.07	0.8440	79.46
140	968.84	0.9723	0.004316	89.45	0 82021	78.37	6.89	66.48	0.8279	80.30
150	1206.0	0.9599	0.005394	94.08	0.77491	72.89	7.08	65.81	0.8111	81.13
160	1528.3	0.9480	0.006761	97.14	0.73356	71.26	7.14	64.12	0.7933	80.83
170	1912.8	0.9354	0.008312	101.00	0.69585	70.28	7.26	63.02	0.7754	81.27
180	2367.2	0.9224	0.01020	103.97	0.66150	68.77	7.31	61.46	0.7566	81.24
190	2899.4	0.9091	0.01240	106.80	0.63023	67.31	7.34	59.97	0.7373	81.34
200	3518.3	0.8955	0.01500	109.08	0.60183	65.65	7.34	58.31	0.7173	81.29
210	4233.0	0.8802	0.01798	111.36	0.57607	64.15	7.34	56.81	0.6964	81.58
220	5053.8	0.8672	0.02145	113.27	0.55273	62.60	7.31	55.29	0.6757	81.82
230	5991.8	0.8518	0.02544	114.92	0.53164	61.10	7.27	53.83	0.6538	82.33
240	7050.6	0.8356	0.03000	116.36	0.51263	59.65	7.22	52.43	0.6312	83.06)
250	8270.5	0.8196	0.0354	116.92	0.49556	57.98	7.12	50.81	0.6075	83.64)
260	9639.8	0.8016	0.0417	116.74	0.48021	56.06	6.97	49.09	0.5821	84.33)
270	11185.0	0.7834	0.0492	115.64	0.46653	53.95	6.78	47.17	0.5554	84.93)

TABLE 14

Brom-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
30°	5.67	1.4815	0.00004702	36.54	1.87985	68.68	3.84	64.84	1.1039	58.74)
100	141.23	1.3864	0.0009519	55.30	1.13159	62.58	4.72	57.86	1.0166	56.93
160	840.81	1.2694	0.005255	68.99	0.79276	54.09	5.07	49.02	0 9174	54.09)
170	1071.6	1.2847	0.006553	72.06	0.75220	54.21	5.18	49.03	0.9000	54.48)
180	1349.3	1 2697	0.008071	75.24	0.71501	53.80	5.29	48.51	0.8822	54.98
190	1679.9	1.2534	0.009911	77.88	0.68085	53.02	5.35	47.67	0.8634	55.21
200	2070.1	1.2385	0.01205	80.49	0.64942	52.27	5.42	46.85	0.8447	55.45
210	2527.0	1.2210	0.01450	83.18	0.62046	51.61	5.48	46.13	0.8250	55.91
220	3057.8	1.2037	0.01750	84.90	0.59370	50.48	5.48	44.93	0.8041	55.87
230	3670.2	1.1876	0.02080	87.21	0.56895	49.62	5.52	44.10	0.7840	56.25
240	4372.5	1.1689	0.02482	88.45	0.54600	48.29	5.49	42.80	0.7617	56.19
250	5173.0	1.1510	0.02927	90.06	0.52467	47.25	5.48	41.77	0.7398	56.44
260	6080.8	1.1310	0.03427	91.72	0.50483	46.30	5.48	40.82	0.7171	56.92
270	7104.8	1.1099	0 04016	92.59	0.48632	45 03	5.43	39.60	0.6929	57.15

TABLE 15

Iodo-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{\frac{1}{3}}-D^{\frac{1}{3}}$	$\frac{L-E_1}{d^{\frac{1}{3}}-D^{\frac{1}{3}}}$
30°	1.48	1.8149	0.00001595	28.11	2.0170	56.70	2.95	53.75	1.1946	44.99
100	50.23	1.7079	0.0004400	42.57	1.2612	53.68	3.62	50.06	1.1193	44.65
190	787.88	1.5627	0.006020	60.87	0.74721	45.11	4.14	40.97	0.9785	41.87)
200	990.60	1.5470	0.007315	63.77	0.71100	45.34	4.28	41.06	0.9624	42.66)
210	1232.0	1.5316	0.008889	66.51	0.67797	45.10	4.38	40 72	0.9456	43.06)
220	1517.1	1.5115	0.01070	69.37	0.64792	44.94	4.47	40.47	0.9272	43.64
230	1851.5	1.4941	0.01296	71.25	0.62066	44.22	4.50	39.72	0.9083	43.73
240	2241.2	1.4764	0.01552	73.32	0.59602	43.70	4.54	39.16	0.8893	44.03
250	2693.2	1.4581	0.01849	75.20	0.57374	43.15	4.56	38.59	0.8695	44.38
260	3214.9	1.4384	0.02199	76.71	0.55395	42.50	4.57	37.93	0.8486	44.68
270	3815.0	1.4172	0.02605	78.06	0.53614	41.85	4.56	37.29	0.8268	45.10

TABLE 16

Carbon Tetrachloride

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T.}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{\frac{5}{8}} - D^{\frac{5}{8}}$	$\frac{L - E_1}{d^{\frac{5}{8}} - D^{\frac{5}{8}}}$
0°	33.08	1.6327	0.0002984	30.27	1.7135	51.87	3.52	48.35	1.1107	43.53
90	1117.0	1.4554	0.007974	50.56	0.89103	45.05	4.43	40.62	0.9334	43.52
100	1464.8	1.4343	0.01026	52.89	0.83580	44.20	4.52	39.68	0.9105	43.58
110	1889.4	1.4124	0.01304	54.99	0.78563	43.21	4.57	38.64	0.8866	43.58
120	2400.8	1.3902	0.01634	57.08	0.73997	42 24	4.61	37.63	0.8623	43.64
130	3009.1	1.3680	0.02024	59.05	0.69855	41.25	4.67	36.58	0.8376	43.67
140	3725.1	1.3450	0.02481	60.92	0.66093	40.26	4.70	35.56	0.8121	43.79
150	4559.6	1.3215	0.03021	62.37	0.62679	39.09	4.67	34.42	0.7860	43.79
160	5524.6	1.2982	0.03650	63.70	0.59581	37.95	4.67	33.28	0.7592	43.83
170	6631.9	1.2734	0.04388	64.66	0.56775	36.71	4.64	32.07	0.7312	43.86
180	7894.8	1.2470	0.05249	65.27	0.54234	35.40	4.57	30.83	0.7020	43.92
190	9326.7	1.2192	0.06250	65.55	0.51927	34.04	4.52	29.52	0.6714	44.00
200	10943.0	1.1888	0.07418	65.42	0.49841	32.61	4.39	28.22	0.6391	44.16
210	12759.0	1.1566	0.08787	64.83	0.47957	31.09	4.26	26.83	0.6051	44.34
220	14793.0	1.1227	0.1040	63.67	0.46257	29.45	4.10	25.35	0.5690	44.55
230	17066.0	1.0857	0.1232	61.80	0.44722	27.64	3.91	23.73	0.5301	44.76
240	19596.0	1.0444	0.1464	59.01	0.43338	25.56	3.65	21.91	0.4875	44.94
250	22496.0	0.9980	0.1754	55.08	0.42093	23.19	3.34	19.85	0.4395	45.16
260	25532.0	0.9409	0.2146	48.99	0.40973	20.07	2.92	17.15	0.3812	44.99
270	28992.0	0.8666	0.2710	39.92	0.39971	15.96	2.34	13.62	0.3063	44.47
280	32825.0	0.7634	0.3597	26.68	0.39071	10.43	1.53	8.90	0.2027	43.90

TABLE 17

Stannic Chloride

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{\frac{5}{8}} - D^{\frac{5}{8}}$	$\frac{L - E_1}{d^{\frac{5}{8}} - D^{\frac{5}{8}}}$
0°	5.88	2.2789	0.00008996	17.84	1.98373	35.38	2.08	33.30	1.2711	26.20
100	498.5	2.0186	0.005764	31.89	0.98455	31.40	2.72	28.68	1.0845	26.45
110	672.7	1.9916	0.007634	33.24	0.92427	30.72	2.76	27.96	1.0612	26.34
120	891.4	1.9639	0.009940	34.54	0.86900	30.02	2.80	27.22	1.0373	26.24
130	1162.0	1.9357	0.01276	35.82	0.81835	29.32	2.83	26.49	1.0126	26.16
140	1491.0	1.9073	0.01616	36.95	0.77193	28.52	2.85	25.67	0.9873	26.00
150	1888.0	1.8772	0.02024	37.93	0.72941	27.67	2.85	24.82	0.9611	25.82
160	2359.0	1.8481	0.02506	38.92	0.69047	26.86	2.86	24.00	0.9345	25.68
170	2914.0	1.8182	0.03077	39.63	0.65482	25.95	2.85	23.10	0.9071	25.46
180	3561.0	1.7873	0.03759	40.00	0.62219	24.89	2.81	22.08	0.8786	25.13
190	4309.0	1.7556	0.04545	40.30	0.59234	23.87	2.77	21.10	0.8494	24.84)
200	5168.0	1.7224	0.05450	40 65	0.56504	22.97	2.74	20.23	0.8195	24.68)
210	6147.0	1.6866	0.06502	40.64	0.54009	21.95	2.68	19.27	0.7882	24.45)
220	7257.0	1.6488	0.07728	40.39	0.51730	20.89	2.61	18.28	0.7554	24.20)
230	8509.0	1.6090	0.09149	39.89	0.49648	19.80	2.52	17.28	0.7212	23.96)
240	9915.0	1.5667	0.1083	38.96	0.47748	18.60	2.42	16.18	0.6847	23.63)
250	11488.0	1.5221	0.1280	37.79	0.46016	17.39	2.30	15.09	0.6463	23.35)
260	13242.0	1.4747	0.1520	36.07	0.44438	16.03	2.15	13.88	0.6045	22.96)
270	15190.0	1.4219	0.1812	33.82	0.43001	14.54	1.98	12.56	0.5586	22.47)
280	17351.0	1.3628	0.2160	31.38	0.41694	13.08	1.81	11.27	0.5087	22.15)

TABLE 18

Water

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	4.569	0.9999	0.000004737	606.5	30.7	575.8	0.9831	585.7)
10	9.140	0.9997	0.000009200	599.5	31.6	567.9	0.9790	580.1)
20	17.393	0.9982	0.00001699	592.6	32.5	560.1	0.9737	575.2)
30	31.510	0.9957	0.00002995	585.7	33.5	552.2	0.9675	570.7)
40	54.865	0.9923	0.00005071	578.6	34.4	544.2	0.9604	566.6
50	91.978	0.9881	0.00008278	571.6	35.4	536.2	0.9524	563.0
60	148.885	0.9833	0.0001303	564.7	36.3	528.4	0.9437	559.9
70	233.308	0.9779	0.0001989	557.6	37.3	520.3	0.9342	556.9
80	354.873	0.9719	0.0002952	550.6	38.2	512.4	0.9240	554.5
90	525.468	0.9655	0.0004273	543.5	39.1	504.4	0.9131	552.4
100	760.000	0.9586	0.0006031	536.5	40.1	496.4	0.9015	550.6
110	1075.37	0.9512	0.0008389	529.4	40.8	488.6	0.8892	549.5
120	1484.0	0.9441	0.001138	522.3	41.4	480.9	0.8766	548.6
130	2019.0	0.9365	0.001522	515.1	42.1	473.0	0.8634	547.8
140	2694.0	0.9283	0.002000	508.0	42.8	465.2	0.8495	547.6
150	3568.0	0.9193	0.002592	500.7	43.7	457.0	0.8349	547.3
160	4652.0	0.9095	0.003313	493.6	44.5	449.1	0.8198	547.8
170	5987.0	0.8989	0.004181	486.2	45.0	441.2	0.8040	548.7
180	7487.0	0.8881	0.005216	479.0	45.4	433.6	0.7878	550.4
190	9403.0	0.8766	0.006439	471.6	46.1	425.5	0.7711	551.8
200	11625.0	0.8646	0.007855	464.3	46.7	417.6	0.7539	553.9
210	14240.0	0.8523	0.009506	456.8	47.1	409.7	0.7363	556.4
220	17365.0	0.8393	0.01140	449.4	47.8	401.6	0.7182	559.1
230	20936.0	0.8256	0.01369	441.9	48.4	393.5	0.6989	563.0
240	25019.0	0.8117	0.01632	423.8	47.8	376.0	0.6791	553.6
250	29734.0	0.7980	0.01944	410.4	47.5	362.9	0.6586	551.0
260	35069.0	0.7840	0.02315	394.0	46.8	347.2	0.6371	544.9
270	41101.0	0.7701	0.02766	374.5	45.6	328.9	0.6142	535.5)

TABLE 19

Methyl Alcohol

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	29.6	0.8101	0.00005620	289.17	16.77	272.40	0.8939	304.7
10	54.7	0.8000	0.00009960	287.36	17.48	269.88	0.8819	306.0
20	96.0	0.7905	0.0001695	284.54	18.03	266.51	0.8692	306.6
30	160.0	0.7830	0.0002772	282.07	18.37	263.70	0.8565	307.9
40	260.5	0.7745	0.0004394	277.78	18.87	258.91	0.8423	307.4
50	406.0	0.7650	0.0006739	274.14	19.16	254.98	0.8269	308.3
60	625.0	0.7555	0.001006	269.41	19.75	249.66	0.8106	308.0
70	926.6	0.7460	0.001465	264.51	20.10	244.41	0.7933	308.1
80	1341.0	0.7355	0.002084	258.96	20.43	238.53	0.7750	307.8
90	1897.0	0.7250	0.002907	252.76	20.70	232.06	0.7557	307.1
100	2621.0	0.7140	0.003984	246.01	20.82	225.19	0.7353	306.3
110	3561.0	0.7020	0.005376	239.27	20.92	218.35	0.7135	306.0
120	4751.0	0.6900	0.007142	232.00	20.95	211.05	0.6911	305.4
130	6242.0	0.6770	0.009379	224.07	20.88	203.19	0.6672	304.5
140	8071.0	0.6640	0.01216	216.12	20.74	195.38	0.6424	304.1
150	10336.0	0.6495	0.01562	206.13	20.55	185.58	0.6160	301.3
160	13027.0	0.6340	0.01994	198.34	20.15	178.19	0.5879	303.1
170	16222.0	0.6160	0.02526	188.25	19.70	168.55	0.5575	302.3
180	20089.0	0.5980	0.03186	177.16	19.01	158.15	0.5255	300.9
190	24615.0	0.5770	0.04010	165.64	18.18	147.46	0.4902	300.8
200	29787.0	0.5530	0.05075	151 84	16.97	134.87	0.4506	299.3
210	35770.0	0.5255	0.06321	134.78	15.29	119.49	0.4045	295.4)
220	42573.0	0.4900	0.08035	112.53	12.92	99.61	0.3464	287.6)
225	46297.0	0 4675	0.1003	99.50	11.54	87.96	0.3114	282 4)
230	50414.0	0.4410	0.1187	84.47	9.87	74.60	0.2697	276.5)
232	52202.0	0.4295	0.1277	77.73	9.14	68.59	0.2509	273.4)
234	53939.0	0.4145	0.1381	70.15	8.29	61.86	0.2287	270.5)
236	55624.0	0.3955	0.1505	61.66	7.27	54.39	0.2020	269.2)
238	57576.0	0.3705	0.1681	50.22	5.96	44.26	0.1663	266.1)
238.5	58329.0	0.3635	0.1789	44.23	5.27	38.96	0.1502	259.4)

TABLE 20

Ethyl Alcohol

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	12.24	0.8062	0.00003300	220.9	11.7	209.2	0.8986	232.8)
10	23.73	0.7979	0.00006207	221.2	12.2	209.0	0.8879	235.4
20	43.97	0.7894	0.0001110	220.6	12.6	208.0	0.8761	237.4
30	78.11	0.7810	0.0001910	220.1	13.0	207.1	0.8633	239.9
40	133.42	0.7722	0.0003150	218.7	13.4	205.3	0.8494	241.7
50	219.82	0.7633	0.0005060	216.0	13.8	202.2	0.8342	242.4
60	350.21	0.7541	0.0007900	213.4	14.2	199.2	0.8178	243.6
70	540.91	0.7446	0.001190	209.9	14.5	195.4	0.8004	244.1
80	811.81	0.7348	0.001740	206.4	14.8	191.6	0.7821	244.9
90	1186.5	0.7251	0.002500	201.6	15.0	186.6	0.7627	244.6
100	1692.3	0.7157	0.003510	197.1	15.3	181.8	0.7425	244.8
110	2359.8	0.7057	0.004860	190.3	15.4	174.9	0.7209	242.7
120	3223.0	0.6925	0.006580	184.2	15.4	168.8	0.6973	242.1
130	4318.7	0.6789	0.008770	177.6	15.5	162.1	0.6727	241.0
140	5686.6	0.6631	0.01152	171.1	15.4	155.7	0.6461	241.0
150	7368.7	0.6489	0.01488	164.7	15.4	149.3	0.6198	241.1
160	9409.9	0.6329	0.01916	156.9	15.2	141.7	0.5910	239.8
170	11858.0	0.6165	0.02446	148.4	14.8	133.6	0.5608	238.2
180	14767.0	0.5984	0.03115	139.2	14.3	124.9	0.5281	236.5
190	18185.0	0.5782	0.03970	128.4	13.6	114.8	0.4919	233.3)
200	22182.0	0.5568	0.05080	116.6	12.6	104.0	0.4523	230.0)
210	26825.0	0.5291	0.06550	103.2	11.4	91.8	0.4057	226.3)
220	32196.0	0.4958	0.08540	88.2	9.9	78.3	0.3511	223.0)
230	38389.0	0.4550	0.1135	70.6	8 1	62.5	0.2849	219.7)
240	45519.0	0.3825	0.1715	40.3	4.7	35.6	0.1703	209.2)
241	46288.0	0.3705	0 1835	35.0	4.0	31.0	0.1499	206.8)
242	47069 0	3.3546	0.1990	28.4	3.3	25.1	0.1239	202.6)
242.5	47463.0	0.3419	0.2164	22.1	2.6	19.5	0.0989	197.2)

TABLE 21

Propyl Alcohol

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	3.44	0.8193	0.00001212	104.4	9.0	185.4	0.9127	203.1
80	376.0	0.7520	0.00104	173.0	11.4	161.5	0.8081	199.9
90	574.0	0.7425	0.00156	169.0	11.7	157.3	0.7895	199.2
100	842.5	0 7325	0.00226	164.0	11.8	152.2	0.7702	197.6
110	1206.0	0.7220	0 00320	159.0	11.9	147.1	0.7497	196.2
120	1683.0	0.7110	0.00443	153.0	12.0	141.0	0.7284	193.6)
130	2293.0	0.6995	0.00605	147.0	12.0	135.0	0.7055	191.3)
140	3074.0	0.6875	0.00805	142.4	12.0	130.4	0.6822	191.1)
150	4052 0	0.6740	0.01060	135.3	11.9	123.4	0.6571	187.8)
160	5264.0	0.6600	0.01380	129.0	11.9	117.1	0.6308	185.6)
170	6695.0	0.6450	0.01770	122.8	11.7	111.1	0.6034	184.1)
180	8383.0	0.6285	0.0225	116.3	11.4	104.9	0.5743	182.7)
190	10466.0	0.6110	0.0282	109.6	11.4	98.2	0.5442	180.4)
200	12801.0	0 5920	0.0353	102.2	10.8	91.4	0.5117	178.6)
210	15575.0	0.5715	0.0442	94.5	10.4	84.1	0.4763	176.6)
220	18679.0	0.5485	0.0556	85.3	9.6	75.7	0.4369	173.2)
230	22154.0	0.5230	0.0704	75.0	8.7	66.3	0.3927	168.8)
240	26194.0	0.4920	0.0904	63.4	7.5	55.9	0.3406	164.1)
250	30785.0	0.4525	0.1180	50.6	6.2	44.4	0.2772	160.2)
260	36103.0	0.3905	0.1610	33.5	4.2	29.3	0.1868	157.0)

TABLE 22

Acetic Acid

Temperature	Pressure	Density of liquid	Density of vapor	$p\Delta v.T/10^6$	A	Latent heat	E_1	$L-E_1$	$d^{1/3}_L-D^{1/3}$	$\frac{L-E_1}{d^{1/3}_L-D^{1/3}}$
20°	11.73	1.0491	0.00007645	.....	.....	84.05	4.88	79.17	0.9737	81.3
30	20.61	1.0392	0.0001264	.....	.....	85.88	5.19	80.69	0.9627	83.8
40	34.77	1.0284	0.0002012	.....	.....	87.02	5.17	81.85	0.9507	86.1
50	56.56	1.0175	0.0003100	.....	.....	88.14	5.81	82.33	0.9381	87.8
60	88.94	1.0060	0.0004621	.....	.....	89.69	6.12	83.57	0.9247	90.4
40	136.0	0.9948	0.0006729	.....	.....	90.43	6.43	84.00	0.9107	92.2
80	202.3	0.9835	0.0009588	.....	.....	91.59	6.71	84.88	0.8959	94.7
90	293.7	0.9718	0.001338	.....	.....	91.88	6.98	84.90	0.8803	96.4
100	417.1	0.9599	0.001833	.....	.....	92.32	7.23	85.09	0.8641	98.5
110	580.8	0.9483	0.002468	.....	.....	92.79	7.47	85.32	0.8474	100.7
120	804.0	0.9362	0.003271	96.24	0.98068	94.38	7.79	86.59	0.8298	104.3
130	1083.0	0.9225	0.004275	101.60	0.91636	93.11	8.02	85.09	0.8112	104.9
140	1431.0	0.9091	0.005516	106.51	0.86227	91.83	8.21	83.62	0.7920	105.6
150	1863.0	0.8961	0.007032	111.21	0.81598	90.74	8.37	82.37	0.7725	106.6
160	2392.0	0.8818	0.008873	115.57	0.77567	89.63	8.49	81.14	0.7519	107.9
170	3034.0	0.8688	0.01084	122.49	0.74002	90.65	8.80	81.85	0.7329	111.7
180	3809.0	0.8554	0.01370	123.89	0.70709	87.71	8.70	79.01	0.7100	111.3
190	4735.0	0.8417	0.01681	127.79	0.67885	86.75	8.78	77.97	0.6880	113.3
200	5836.0	0.8264	0.02052	131.21	0.65202	85.55	8.83	76.72	0.6646	115.4
210	7134.0	0.8117	0.02488	134.23	0.62709	84.17	8.85	75.32	0.6409	117.5
220	8655.0	0.7943	0.03021	135.87	0.60374	82.02	7.77	73.25	0.6147	119.1
230	10426.0	0.7758	0.03626	137.82	0.58171	80.16	8.72	71.44	0.5879	121.5
240	12475.0	0.7576	0.04327	139.43	0.56084	78.18	8.64	69.54	0.5605	124.1
250	14832.0	0.7358	0.05163	139.69	0.54097	75.55	8.50	67.05	0.5304	126.4
260	17527.0	0.7138	0.06165	138.42	0.52199	72.26	8.26	64.00	0.4986	128.4
270	20590.0	0.6896	0.07364	135.64	0.50381	68.33	7.95	60.37	0.4643	130.0
280	24055.0	0.6596	0.08834	130.33	0.48637	63.39	7.50	55.89	0.4251	131.5
290	27951.0	0.6337	0.1073	121.83	0.46963	57.21	6.89	50.32	0.3837	131.2
300	32312.0	0.5956	0.1331	107.95	0.45350	48.95	6.00	42.95	0.3308	126.8
310	37168.0	0.5423	0.1718	86.23	0.43798	37.77	4.71	33.06	0.2595	127.4
320	42550.0	0.4615	0.2501	42.64	0.42301	18.04	2.29	15.75	0.1353	116.4